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The Relationship between Executive Functioning Skills and Mathematical Achievement: A Cross-Sectional Correlation Study



A dissertation submitted in partial fulfillment of the requirements for the degree of Master of Science in EducationMSc (Child Development & Education)

August 2022

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Abstract

The aim of this study was to investigate the relationship between executive functions (working memory and inhibition) and academic achievement, specifically math achievement, and examine whether the relationship was significantly moderated by gender. The associations between a measure of math achievement and executive functioning tasks were examined. Gender was explored as a possible moderator in this relationship. The participants were 28 7- 8 year-old children from the United States. Results indicated that working memory was positively and significantly correlated with math achievement, however there was no significant relationship between inhibition and math achievement. Working memory was found to be predictive of math achievement. Gender was not found to account for significant variance in math achievement, nor were significant gender differences found for any measures. These data provide support for a positive relationship between working memory and math achievement, but lacks sufficient evidence of a relationship between inhibition and math achievement, as well as a moderating role of gender in the relationship between executive functioning and math achievement.

Chapter 1: Introduction

1.1 Background

The aim of the current study is to examine the relationship between executive functioning and academic achievement, namely math achievement, and to investigate whether the relationship is significantly moderated by gender in a sample of 7-8 year old children.

Executive functioning can be thought of as the use of top-down mental processes to accomplish planning, guiding, and organizing goal-directed behavior (Dekker et al., 2017; Diamond, 2013). Core executive functions are typically considered to be working memory, inhibition, and shifting. The present study will focus on the former two components. Working memory may be considered temporary storage and manipulation of information for complex cognitive tasks (Baddeley, 1992). Inhibition is the deliberate suppression of dominant, automatic, or prepotent responses (Miyake et al., 2000). The present study utilizes tasks relating to each of these components of executive functioning to explore whether a relationship exists between these executive functions and math achievement in 7-8 year old children.

Gender differences in the rates of referral, diagnosis, and subsequent treatment of Attention Deficit Hyperactivity Disorder (ADHD) have been recorded (American Psychiatric Association, 2013). ADHD is also highly correlated with executive dysfunction **(**Nigg et al., 2005; Willcutt et al., 2005). For this reason, this study sought to examine if there was a relationship between executive functioning and academic achievement, and whether it was moderated by gender.

1.2 Study Rationale

Students are often referred for potential diagnosis of ADHD based on academic underachievement and disruptive behaviors. Given the strong association between executive functioning deficits and poor academic performance, identifying whether specific executive functioning components may serve as predictors of academic achievement, specifically math achievement, may inform educators' decision-making when it comes to appropriately supporting students who may be struggling academically.

Additionally, ADHD, which is partly characterized by diminished executive functioning skills, is more frequently diagnosed in male students than in female students at a young age at an estimated ratio of 2:1 (American Psychiatric Association, 2013). Girls are diagnosed with ADHD

at a later age than boys, and potentially may be underdiagnosed. The most common reason for boys' referral for diagnostic processes is hyperactive behavioral markers (Klefsjö et al., 2021). Meanwhile, girls are more likely than boys to be referred to a clinician for an emotional problem, and then later be diagnosed with ADHD (Klefsjö et al., 2021). There is a gap in the literature examining the diagnostic process of ADHD from a gender perspective, and results of the present study may inform the way screening for ADHD in educational settings takes place.

Our hope is that the findings of this study may inform instruction of children with executive functioning deficits, including children with ADHD, and those with low math achievement, by elucidating the patterns of executive functioning difficulties and math achievement in a sample of 7- and 8-year-old children. The pattern of relationships across gender could shed further light as to the nature of relationships between executive functioning and math skills.

1.3 Structure of the Dissertation

The second chapter presents the literature review, which describes the key constructs of this study, and how they have been found to relate to one another in previous research. Executive functioning and its main components will be discussed, followed by some insights into how each component may relate to academic achievement, particularly mathematics. Also discussed is the association between executive functioning and attention deficit hyperactivity disorder (ADHD) and how the gender differences observed in ADHD may potentially play a role in the relationship between executive functioning and academic achievement.

The third chapter presents an outline of measures and methods used for this study. This includes information about recruitment, experiment design, data collection procedures, and subsequent statistical analyses.

The fourth chapter shall outline the results for each research question. It includes overviews the statistical analyses which have been carried out, in the form of tables.

The fifth and final chapter discusses the results. This involves potential reasonings for the results and lack of results pertaining to each research question. Additionally, limitations of the present study are detailed and future directions for research are suggested.

Chapter 2: Literature Review

2.1 What is Executive Functioning?

Executive functioning skills can be defined as the cognitive abilities for planning, guiding, and organizing goal-directed behavior and mental processes (Dekker et al., 2017) and are thought to play a role in learning and academic achievement (Baggetta & Alexander, 2016). Research of executive functioning has grown increasingly popular in recent years, as experts in the field more clearly define it, and the skills it comprises.

Executive functioning is an umbrella term for a number of separate but related skills which allow for higher order thought processes and implicate similar patterns of brain activations, called neural correlates. The frontal lobe is typically credited with being the location of executive functioning in the brain, particularly the prefrontal cortex (Jurado & Rosselli, 2007). This neural correlate has been established based on research with patients following an injury in the prefrontal cortex, who then exhibited similar patterns of diminished cognitive abilities. A study characterized patients with frontal lobe damage as having impairments in planning, coordinating, and controlling sequences of action, and generally a failure to achieve known goals. Based on neuroimaging studies, the prefrontal cortex, which is located in the frontal lobe, is activated when completing tasks which involve problem solving, memory retrieval, prospective memory and attention shifting (Ramnani & Owen, 2004). Neuroimaging also suggests that the prefrontal cortex is responsible for abilities which coordinate information processing and transfer between cognitive operations.

Based on the broad collection of studies dedicated to executive functioning, a predominant framework denoted by three separate but related components has emerged. Those three components are shifting, inhibition and working memory/updating and were labeled by Miyake and colleagues (2000) from a latent variable analysis. This three-factor model is further supported by a recent systematic review. The review looked at 5,000 samples in a confirmatory factor analysis and found that shifting, inhibition, and working memory/updating were positively correlated, but are distinguishable in middle childhood. Further research has developed a number of complex executive tasks, which these three components relate to differentially, lending further support to their distinctiveness.

2.1.1 Shifting

Shifting refers to the ability to shift (or switch) between multiple mental sets, tasks, or operations (Monsell, 1996). This can be switching between different subtasks, or elements of the same task (Fisk & Sharp, 2004). Studies investigating shifting in samples of children commonly use card-sorting paradigms (sorting series of cards with various stimuli according to changing rules) and trail-making tasks (connecting a set of randomly arranged numbered dots as quickly as possible) as indicators of this component (Karr et al., 2018).

While researchers generally agree that shifting abilities are distinguishable in adults, multiple exploratory factor analyses in samples of children variably distinguish shifting from other skills (Karr et al., 2018; St Clair-Thompson & Gathercole, 2006). This suggests that shifting may emerge later in development.

2.1.2 Inhibition

Inhibition has been defined as the ability to deliberately inhibit dominant, automatic, or prepotent responses in the context of changing internal or external demands (Congdon et al., 2012; Miyake et al., 2000). Executive functioning tasks in which performance is primarily attributed to inhibition abilities usually assess either inhibition of a strongly triggered response or impulsive responding in the absence of strong trigger-schema contingencies (Bayliss & Roodenrys, 2000). Evidence from Bayliss and Roodenrys (2000) suggests that performance on tasks where strongly triggered responses must be inhibited may be significantly poorer in clinical samples of children with Attention Deficit Hyperactivity Disorder (ADHD) when compared to control samples and learning disabled samples. Karr et al. (2018) suggest that the Stroop paradigm (naming the color of the text of a color word, rather than the color word itself) is among the most commonly used indicators for inhibition in children, along with the Go/No Go paradigm (participants must respond to a stimulus in one condition and ignore the same stimulus in another).

2.1.3 Working Memory

Working memory has been defined as the ability to temporarily store, manipulate, and control incoming information simultaneously (Dekker et al., 2017). Some studies refer to this phenomenon as ‘updating’, however in the current study we use the term ‘working memory’.

Baddeley and Hitch (1974) proposed a widely used model of working memory in which a central executive coordinates the information of two interacting slave systems, a phonological loop for verbal processing, and a visuospatial sketchpad. Some key paradigms for looking at working memory in children are digit span tasks (reciting a string of presented numbers in forward or backward order), and letter-number sequencing tasks (listening to a string of letters and numbers and reciting them back in alphabetical or numerical order; Karr et al., 2018).

2.1.4 Executive Functioning Task Impurity

The surge in executive functioning research in recent years has uncovered difficulties when it comes to measurement. As previously mentioned, the different components of executive functioning correlate with each other, and as such, any task targeting one component likely implicates others (Miyake et al., 2000). This has been identified as a task impurity issue, in which one task may assess or operate on multiple executive functioning processes, as well as non-executive functioning processes (Baggetta & Alexander, 2016). Bagetta and Alexander (2016) discussed the challenge this poses in inferring what any particular task is measuring. They also suggest that this problem affects more complex executive functioning tasks to a greater extent; however even simpler tasks are largely confounded by overlapping executive networks. One method recommended to account for task impurity is the use of multiple exemplar tasks in a testing battery which target the same executive functioning component, followed by using factor analysis to create a latent variable for that target construct, extracting what is common across tasks to achieve a more pure measure of that component (Miyake & Friedman, 2012).

2.2 Executive Functioning and Academic Achievement

Previous research presents strong evidence of a relationship between executive functioning and academic achievement (e.g., Best et al., 2011; Blair & Razza, 2007). It has been suggested that several learning skills associated with high academic achievement require efficient use of these executive functioning skills. Based on prior research, executive functioning is theorized to play a causal role in the development of academic skills and knowledge (St Clair-Thompson & Gathercole, 2006). Working memory is considered to constrain mental arithmetic (DeStefano & LeFevre, 2004), and inhibition has been found to uniquely contribute to academic ability (Blair & Razza, 2007). St Clair-Thompson, and Gathercole (2006) also suggested that

inhibition in particular is supportive of general academic learning, as they found associations between a latent variable for inhibitory control and measures of attainment for both math and literacy. As such, children with good executive functioning skills are thought to utilize them to establish strategies which facilitate successful learning and high performance on standardized measures of academic achievement.

Understanding how the components of executive functioning relate to academic attainment across curricular areas is of interest for educators. Informing teachers of the executive functions which may underlie attainment may motivate them to incorporate facets of the related cognitive skills into everyday learning activities. Strong previously reported evidence suggests that strengthening executive functioning skills may be advantageous for academic outcomes, and therefore recent research has aimed to identify which executive functions may be associated with different content areas.

2.2.1 Shifting and Achievement

There are limited findings to report regarding shifting skills and their association with academic achievement. This is likely in part due to studies variably adopting a two factor model of executive functioning in children, rather than a three factor model which includes shifting.

When a factor for shifting is included in research, findings are few and may be weak or inconsistent regarding associations with achievement. One study by van der Sluis et al. (2007) found shifting to account for a small but significant portion of variance in non-verbal reasoning and reading abilities in a sample of children aged 9-12 years; however, shifting was negatively correlated with reading, despite reading positively correlating with other executive functions in the same study. A longitudinal study found performance on a shifting task to predict reading and math performance at each time point, but preschool task performance did not predict reading or math at age 7 (Bull et al., 2008). The authors suggested this might indicate that shifting is a skill which is more apparent in complex problem solving, which would require students to attend to different components of a problem, and as such there may be minimal variability in shifting task performance in young children. These findings from van der Sluis et al. (2007) and Bull et al. (2008) demonstrate that evidence for a relationship between shifting and any academic content area is inconclusive, as it did not account for great variance in achievement, nor was it predictive

of achievement in school-aged children. Together, these findings do not indicate any certain associations.

2.2.2 Inhibition and Achievement

There is substantial evidence to support an existing relationship between inhibition and achievement especially in early academic competencies as discussed by Blair and Razza (2007). When controlling for general intelligence, an inhibition task was found to correlate independently with early math, letter-knowledge and phonemic awareness skills, and teacher-reported inhibitory control was found to correlate with math and letter-knowledge aspects of literacy abilities in a sample of 3-5 year-old children. They propose that their findings lend support to an inhibitory account of the development of executive functioning, suggesting that inhibiting a prepotent response despite distractors is a unique contributor to developing academic abilities. When controlling for working memory, significant associations between inhibition and standardized assessments in math, English, and science were found in a sample of 11-12 year-old children (St Clair-Thompson & Gathercole, 2006). The authors suggest that this demonstrates how inhibition may play a role in blocking out irrelevant information when reading or problem solving. However, the same study found associations of a much greater magnitude between working memory and academic standardized assessment scores. It is clear that inhibition relates to achievement measures, however St Clair-Thompson and Gathercole (2006) highlight the substantial involvement of working memory as well.

2.2.3 Working Memory and Achievement

Working memory is consistently found to relate to academic achievement. Gathercole et al. (2004) found that in a sample of 7 year-old children in the UK, attainment on the national curriculum assessments in math and English was significantly associated with working memory scores. This finding lends support to the idea of Gathercole and Pickering (2001) that the cognitive demands of processing and storing math computations may be supported by the workspace provided by working memory. They also suggest that their findings relating to emerging literacy reflect the implication of working memory in developing skills for processing and storing material simultaneously.

Gathercole et al. (2006) conducted a study in which researchers observed 5-6 year-old students who had scored poorly on measures of working memory in a classroom setting. Profiles of the students emerged showing patterns of forgetting instructions, failing to cope with simultaneous processing and storage demands, losing track in complex tasks, sentence writing, and carrying out mental arithmetic. These observations demonstrate the potential constraints to classroom learning posed by working memory deficits.

St Clair-Thompson and Gathercole (2006) found differentiated associations between verbal working memory and visuospatial working memory. Verbal working memory associated with English attainment, and visuospatial working memory corresponded with attainment in English, math and science. From this, they proposed a causal role of working memory in development of skills and knowledge, and suggested this may be particularly pertinent in literacy given its relationship with both working memory systems.

In sum, working memory is significantly associated with achievement across multiple subject areas, and this idea is further supported by the substantial learning difficulties observed in children with poor working memory. Additionally, the relationship between working memory and achievement may be broken down, as the slave systems of visuospatial and verbal working memory differentially relate to academic attainment in different subject areas.

2.3 Executive Functioning and Math

The present study focuses on the relationship between math achievement and executive functioning. Math was selected over other subject areas because of the abundance of literature which consistently suggests that it is associated with executive functioning in school-aged children.

Research from the field of cognitive neuroscience provides support for an association between math and executive functioning. Neuroimaging studies indicate evidence of an overlap of the neural substrates which support quantitative reasoning and executive functioning (Dehaene et al., 2004; Klingberg, 2006). As previously mentioned, there is agreement that frontal lobe activity relates to executive functioning skills (Anderson, 2002). According to Jurado & Rosselli (2007), the parietal lobe is also likely involved, particularly in attentional processes. Evidence from neuroimaging found activity in front cortical areas in response to number tasks and tasks involving representation of quantities, providing evidence of both executive

functioning and math skills being localized in the frontal and parietal lobes (Dehaene et al., 2004). Math skills are also largely associated with activation in the parietal lobe, in particular the intraparietal sulcus (Klingberg, 2006). This localized brain region seems to be involved in representing quantity and retrieving answers to simple calculations (Klingberg, 2006). The overlapping brain region activation patterns in the frontal and parietal lobe during math and executive functioning tasks suggest an association between working memory skills and math problem solving.

There is much to be learned about this relationship from a 2013 meta-analysis on executive functioning and mathematics in children aged 4-12 years. Friso-van den Bos et al. (2013) investigated the associations between executive functioning components and math across 111 studies. Results of the meta-analysis indicated significant moderate correlations between math and shifting, inhibition, verbal working memory, and visuospatial working memory. The authors determined that strengths of associations varied between the different executive functioning components, and therefore they investigated several moderating variables to uncover why this might be. Variation in strength of associations was consistently explained by the type of math test used in studies, so the meta-analysis yielded rich information as to the elements of mathematics which related to each executive functioning component. This will be discussed in the subsections which follow, along with supporting extant literature.

It is important to examine the types of math skills commonly exercised by elementary school-aged children, and interpret how children at this age might utilize executive functioning to master math skills. St. Clair-Thompson and Gathercole (2006) suggest that elementary math skills such as mental arithmetic, measurement abilities, and spatial abilities all rely greatly on retention and manipulation of information in working memory. Mastering elementary-level math skills often demands attending to only relevant information, and therefore inhibiting distractors, irrelevant information, or prepotent responses, which implicates inhibition in math achievement (Dekker et al., 2017; Welsh et al., 2010). Based on prior literature, it is likely that math skills developed at ages 7 and 8 and placed high demands on executive functioning, particularly working memory and inhibition.

2.3.1 Shifting and Math

There are few and inconsistent findings regarding shifting and its association with academic achievement. Examining its relationship with mathematics does not provide much clarity as to the nature of this association. van der Sluis et al. (2007) failed to find any significant relationship between shifting and mathematics. In contrast, many studies have found significant associations (Bull et al., 1999; Bull & Scerif, 2001; McLean & Hitch, 1999; van der Sluis et al., 2004). van der Sluis et al. (2007) theorized that they failed to find a significant relationship because they controlled for the non-executive function of naming speed, which was not the case in previous studies where an association was found. For this reason, van der Sluis et al. (2007) suggested that this finding may indicate that the relationship between shifting and math skills in previous research could in part be due to the non-executive demands placed on children in performance of tasks used as paradigms for shifting.

Friso-van den Bos et al. (2013) did find a medium-sized positive correlation between shifting and math achievement in their meta-analysis. It is worth noting that of the 111 studies included in the meta-analysis, only 18 included shifting, further demonstrating that limited research which includes shifting as an executive functioning component in children exists. Of the executive functioning components included in the meta-analysis, shifting had the weakest correlation with math skills. The authors suggested that this may be indicative of the lesser relevance of shifting when it comes to math.

Given such inconsistent results, it is likely that prioritizing investigation of other executive functioning components' relationships to achievement may yield results which provide more clear implications for informing instruction practices. Thus, we did not include tasks relating to shifting abilities in our assessment battery.

2.3.2 Inhibition and Math

There is a greater body of research suggesting a relationship between math skills and inhibition. A 2001 study by Bull and Scerif found mathematical abilities to correlate with all executive functioning components in a sample of 6-8 year-old children, including inhibition. The authors stated that children who had performed poorly on inhibition measures also seemed to

struggle with inhibition of inappropriate and irrelevant previously learned strategies on math problems. Poor inhibition may then prevent relevant information from entering working memory, and therefore prevent the appropriate strategy from being deployed, hence the poor performance on math assessments.

However, there are still some inconsistencies in findings regarding inhibition's association with math skills. Dekker et al. (2017) found significant correlations between math ability and all executive functions except for inhibition, measured both through parent and teacher rating scales, as well as Go/No Go task performance. Dekker et al. (2017) recommended that perhaps significant correlations are more likely to appear amongst children with greater difficulty with inhibitory control or math skills. Results of Bull and Scerif (2001) and Dekker et al. (2017) taken together imply a potential moderating role of sample type in the association between inhibition and math skills.

As was mentioned previously, the meta-analysis by Friso-van den Bos et al. (2013) found significant moderate correlations between inhibition and mathematics. However, after shifting, inhibition was the next weakest of the correlations, with both verbal and visuospatial working memory being significantly more strongly correlated with math. The authors suggested that a potential reason for a weaker relationship between math and inhibition may be that inhibition of irrelevant visuospatial information, such as in math problem solving, may be less effortful than inhibition of irrelevant verbal information. Thus inhibition of irrelevant visuospatial information may place less of a demand on cognitive resources.

2.3.3 Working Memory and Math

An abundance of evidence indicates a strong relationship between measures of working memory and math achievement, however different elements of math skills may be linked to each of the slave systems of working memory. St Clair-Thompson and Gathercole (2006) found a close relationship between mathematics and working memory, which they stated lent support to the perspective that working memory capacity in part determines mental arithmetic and mathematics performance. They argued that working memory contributes to the ability to master skills such as counting, mental arithmetic, measurement abilities, and space abilities, all of which contribute to competence in curriculum-based mathematics. This association is further specified by DeStefano and LeFevre (2004), who investigated the role of working memory in mental

arithmetic specifically in a review. Their findings further elucidate the nature of working memory demands for different conditions of employing math skills. DeStefano and Lefevre reported evidence of the involvement of the central executive in general attentional requirements of retrieving math facts from memory. The phonological loop was found to be implicated in multi-digit operations and in simple arithmetic when counting is used for problem solving. Based on the findings of Logie et al. (1994) it was suggested that the visuospatial sketchpad may be involved in arithmetic encoding for visually presented math problems. However, DeStefano and LeFevre (2004) indicated that there were too few findings on the role of the visuospatial sketchpad in the relationship between working memory and math to draw any conclusions.

This relationship can also be observed when highlighting those children who may perform very poorly, or highly, on measures of working memory. Children who perform poorly on measures of working memory were found to be more likely to make errors in math learning activities (Gathercole et al., 2006). This might be due to difficulties with evaluating new strategies for problem solving in newly learned tasks in school (Bull & Scerif, 2001). Gathercole et al. (2004) found that the children who scored the highest on standardized math tests outperformed average and poor academic scoring children on measures of working memory, including backwards digit span, listening recall, digit recall, and word list matching. It was also found that working memory scores could discriminate between the children who had performed poorly on math attainment measures from the rest of the sample (Gathercole et al., 2004).

In the meta-analysis by Friso-van den Bos et al. (2013), working memory was significantly correlated with math, and correlations for verbal working memory were significantly stronger than those of all other executive functioning components, with visuospatial working memory having the next strongest correlation. This suggests that working memory, particularly verbal working memory, is especially salient in math performance. The authors stated that their findings supported the idea of Dehaene (1997) that working memory skills promote the storage and retrieval of solutions in math problems, as well as retention of crucial information in problem solving. Interestingly, visuospatial working memory, along with shifting and inhibition, correlated more strongly with general math tests, while verbal working memory correlated more strongly with purely arithmetical measures. There were not enough studies

finding this relationship with visuospatial working memory and general math tests, however, there was strong evidence to implicate verbal working memory in arithmetic.

2.4 Executive Functioning and ADHD

Attention Deficit Hyperactivity Disorder (ADHD) can be characterized by impulsivity, hyperactivity, and inattention (Neely et al., 2016). According to the National Institute of Mental Health (2022), the median age of diagnosis of ADHD in children is 6 years, with the median age of mild ADHD being 7 years. The prevalence of ADHD has also increased in recent years. In 2011, it was recorded that 11% of children were diagnosed with the disorder at some point in childhood (Attention-Deficit/Hyperactivity Disorder (ADHD), 2022). There are different ways in which ADHD may present in children. The combined subtype of ADHD can be considered cases of the disorder where an individual displays hyperactive, impulsive, and inattentive behaviors (Hasson & Fine, 2012). In the inattentive subtype, inattention is the primary characteristic (Hasson & Fine, 2012).

2.4.1 Commonalities between Executive Functioning Deficits and ADHD

There is substantial overlap between the impairments displayed by children with ADHD and the deficits associated with poor executive functioning. On a neural level, Spencer-Smith and Anderson (2009) reported that the structural and functional brain abnormalities associated with ADHD occur in regions associated with executive functioning, such as the prefrontal cortex. Prefrontal lesions have been found to cause hyperactivity, distractibility, and impulsivity along with poor executive functioning task performance (Fuster, 1997). Children diagnosed with ADHD also often demonstrate difficulty with executive functioning skills. They struggle with inhibition of prepotent responses (Bayliss & Roodenrys, 2000), working memory tasks, planning, and organization (Gioia et al., 2002). According to Takeuchi et al. (2013), ADHD is uniquely associated with verbal working memory deficits, as inattention symptoms were associated with poor verbal working memory. Based on such associations, earlier researchers considered ADHD to be the manifestation of executive dysfunction (Gioia et al., 2002).

2.4.2 The Relationship between Executive Functioning and ADHD

A 2005 meta-analysis by Willcutt et al. investigated the relationship between executive functioning and ADHD symptomatology across 83 studies. Findings that ADHD symptoms

differentially related to executive functioning weaknesses support the idea that executive functioning impairments alone are not the primary deficit of ADHD. Phrased differently, the meta-analysis supports the idea that executive functioning deficits are some of the symptoms of ADHD, but there are other ADHD symptoms which are not executive functioning deficits.

The findings of Willcut et al. (2005) indicated that ADHD was significantly associated with weaknesses in multiple executive functioning components. The most consistent significant group differences between participants with ADHD and control participants across studies were on stop-signal reaction time and continuous performance omission errors, both of which are often considered to be measures of inhibition. Fewer studies examined the relationship between working memory and ADHD symptoms, but from those which did, significant group differences were found. However, the weakest group difference of all the executive functioning measures included in the study was with the Wisconsin Card Sorting Task perseverative errors, which is typically considered a measure of shifting. Taken together, the results of the meta-analysis indicate the strongest relationship between measures of inhibition and ADHD symptoms, followed by measures of working memory, and with a weaker relationship with measures of shifting.

The authors of many studies in the meta-analysis by Willcutt et al. (2005) suggested that executive functioning weakness could provide support for discriminant validity between inattentive and combined subtypes of ADHD. Measures of inattention were consistently significantly associated with executive functioning weaknesses, however in studies which included measures of hyperactivity and impulsivity, those symptoms were not independently associated with executive functioning performance when the influence of inattention was controlled. This finding suggests that executive functioning deficits may be a more prominent symptom of the inattentive-subtype of ADHD than the combined-subtype. However these findings should be taken with caution, as this finding is weakened due to fewer studies in the meta-analysis including hyperactivity and impulsivity measures.

2.5 ADHD, Executive Functioning, and Achievement

Given the associations between ADHD and executive functioning, and between executive functioning and academic achievement, it is unsurprising that there is also an association between ADHD and academic achievement. Several studies report poor achievement and

learning difficulties among children with ADHD (Barry et al., 2002; Dupaul et al., 2001; Polderman et al., 2010; Spira & Fischel, 2005). However Biederman et al. (2004) found that children who had both ADHD and executive functioning deficits were at greater risk for decreased academic achievement compared to children with ADHD alone. Based on this finding, it may be that both executive functioning deficits and ADHD have negative effects on academic achievement, however, children with an ADHD profile including poor executive functioning are likely to experience more difficulties with academics. Antonini et al. (2016) found that executive functioning task performance was causally related to both ADHD and math performance such that it mediated the relationship between ADHD and math performance. Considering this body of evidence, executive functioning can be considered a critical determinant of academic achievement particularly among children with ADHD. This serves as rationale in the present study for investigating executive functioning and academic achievement, specifically math.

2.6 Gender differences in ADHD

Prior literature has established links between executive functioning, academic achievement, and ADHD. But one area which has yet to be extensively investigated is how gender may relate to executive functioning. As discussed previously, there is evidence of different profiles of ADHD, such that executive dysfunction characterizes some, but not all, cases (Nigg et al., 2005; Willcutt et al., 2005). The following section will discuss another characteristic in different ADHD profiles: gender. It may be the case that a relationship exists between executive functioning and gender.

2.6.1 Gender Discrepancy in ADHD

Rates of referral and diagnosis for ADHD by gender vary across sources, but the general consensus is that boys are referred for and diagnosed with ADHD more frequently than girls (American Psychiatric Association, 2013). A recent review of literature concerning ADHD and gender suggests that the prevalence of ADHD in boys is 2-2.5 times higher than in girls (Hinshaw et al., 2022). There remains much to learn about ADHD and gender differences, because the discrepancy in diagnosis rates by gender has resulted in fewer studies including girls with ADHD in their sample, and as such, a lack of knowledge about ADHD in girls (Gershon & Gershon, 2002). Hinshaw et al. (2022) suggested several reasons for the underrepresentation of

girls within ADHD in research. One is the predominance of inattentive subtype of ADHD, as well as lower rates of disruptive behaviors in women and girls, so girls' symptoms may be less overt and therefore go unnoticed. Another reason may be the higher rates of compensatory behaviors, masking ADHD symptoms and also contributing to either underdiagnosis or a much later diagnosis of ADHD in girls.

Klefsjö et al. (2021) postulated some potential explanations for why fewer girls are diagnosed with ADHD, and typically at an older age, than boys. These include the aforementioned theory that boys' more hyperactive profile of the disorder is more disruptive and therefore action is taken sooner, but also, based on there being higher rates of internalizing disorders in girls with ADHD, it is thought that inattentive profiles go unnoticed until an emotional disorder, such as anxiety, becomes apparent later in childhood. Klefsjö et al. imply that the toll of the social, academic, and emotional difficulties surrounding undetected and untreated ADHD may contribute to eventual internalizing emotional disorders that many girls with ADHD go on to develop.

2.6.2 ADHD Symptoms by Gender

ADHD may present differently in boys and girls. Previous literature provides evidence that the different profiles of ADHD may have different prevalence rates between genders. Typically, studies report that boys with ADHD more often exhibit the combined subtype, demonstrating high impulsivity and hyperactivity, whereas girls with ADHD often exhibit the inattentive subtype (Elkins et al., 2011; Kok et al., 2016). The review by Hinshaw et al. expanded on this, finding that girls showed predominantly inattentive symptoms, and also had more internalizing problems, while boys were more hyperactive, impulsive, and demonstrated more externalizing problems. In another meta-analysis, Gaub and Carlson (1997) found that compared with boys with ADHD, girls with ADHD demonstrated greater intellectual impairment. In a meta-analysis of studies using continuous performance tests as measures of inattention and inhibitory control, most studies reported that boys were more likely to commit commission errors, indicating an error in inhibition, suggesting that inhibition may be mediated by gender (Hasson & Fine, 2012). Difficulty with inhibitory control is characteristic of impulsivity, and thus, this finding strengthens the theory that boys with ADHD more commonly have a combined subtype of ADHD than girls.

Given the relationship of ADHD and gender, the relationship of ADHD and executive functioning, and the relationship of executive functioning and achievement there may be a moderating role of gender in the relationship between executive functioning and academic achievement, which the present study seeks to examine.

2.6.3 Executive Functioning, Math Skills, ADHD, and Gender

Few studies explore how the relationship between executive functioning and math achievement might differ by gender. One study which investigated this amongst children with ADHD explored whether processing speed and working memory contribute to math computation ability (Sturm et al., 2018). It was found that working memory was predictive of math achievement across genders and in samples of both typically developing children, and children with ADHD. Interestingly, Sturm et al. found gender differences in math achievement in children with ADHD when taking into account levels of anxious perfectionism. Among the children who scored low on measures of anxious perfectionism, slower processing speed predicted poorer math computation in boys with ADHD than for girls.

2.7 The present study

There is widespread support in the literature for a connection between executive functioning and academic achievement, and that working memory and inhibition are executive functioning components which are often associated with academic achievement. Mathematics is consistently found to be an academic subject area with a strong association with executive functioning. There is also evidence of a connection between ADHD symptoms and executive functioning deficits. There is a clear gender discrepancy whereby more boys than girls are diagnosed with ADHD, and girls with ADHD are diagnosed later than boys on average. This could potentially be due to the presentation and prevalence of different subtypes of the disorder across genders. Between the two subtypes of ADHD, there is evidence to suggest there may be distinct patterns of associations with executive functioning deficits, and areas of academic attainment. Since executive functioning is linked to academic achievement as well as ADHD, this study seeks to examine the relationship between executive functioning and academic achievement, specifically math achievement, and to investigate the potential moderating role of gender within this relationship.

Based on the literature reviewed here, we aimed to address the following research questions:

1. Is there a relationship between math achievement and executive functioning?
    a. Is there a relationship between math achievement and a task relating to working memory?
    b. Is there a relationship between math achievement and a task relating to inhibition?
2. Is there a moderating role of gender in the relationship between math achievement and executive functioning?

Math achievement was captured as a latent variable from scores on arithmetic tests. Working memory was operationalized through a digit span task, and inhibition was operationalized through a Go/No Go task. The goal of this study was to investigate how components of executive functioning relate to math achievement, and whether relations were moderated by gender.

Based on previous literature, it was hypothesized that there would be a significant correlation between a task relating to working memory (digit span) and math achievement (TOBANS arithmetic subtests), as well as between a task relating to inhibition (Go/No Go) and math achievement. In regards to the second research question, it was hypothesized that gender would moderate the relationships between math achievement and executive functioning measures.

Chapter 3: Methods

3.1 Participants

Participants originally included 28 7-8 year old children (mean age 94 months, female n=10) from the United States. The participants comprised a convenience sample, recruited through digital advertisements circulated by schools, social media, and sharing amongst community members. Snowball sampling was also used, as several participants expressed interest in the study after being referred by a participant who had already completed the study. Participants completed the study through an online behavioral experiment tool while on a video call with the principal investigator. There was a child who exited the browser window of the experiment before her responses to a particular subtest could be saved, and therefore her data were removed before analyses commenced. Thus, 27 children completed all measures and were included in the final sample. The mean age of the 27 children included in the sample was 94 months and there were more male than female participants (66% male). Data collection took place between May and June of 2022.

3.1.1 Ethical considerations

This study received ethical approval from the Central University Research Ethics Committee at the University of Oxford (Ref: CIA-22HT-028, Appendix A).

Families were recruited using digital posters circulated in communities via email and social media (Appendix B). Parents and guardians were invited to contact the researcher to express interest in enrolling their child in the study. Those families who contacter the research were sent the study information sheet, to inform their decision to enroll their child in the study. After reviewing the study information sheet (Appendix C), parents and guardians were invited to complete a survey (Appendix D) in which they could give consent to their child's participation in the study. Additionally, at the start of each data collection session, each participant gave assent to their own participation in the study (Appendix E).

3.2 Procedure

Parents and guardians completed a brief survey in order to consent to their child's enrollment in the study and select a date and time for data collection. Participants' date of birth and gender were also recorded via the parent survey.

Participants met with the researcher for one session of data collection via video call. The researcher used a script to explain the study information and information for each task in order to standardize instructions across participants (Appendix I). The researcher began the meeting with a brief explanation of the study using child-friendly language. Participants were asked if they understood the explanation and given the opportunity to ask any questions they had before assenting to their participation. If a parent or guardian was present with the child on the call, the researcher informed them that they were welcome to supervise the child and provide technical support as needed, but that their child's data would be invalidated if they interfered with any of the tasks. The researcher shared a link via the chat function of the video conferencing tool. The link led the participant to the online experiment tool website, Gorilla, where the tasks for the study could be accessed. Participants completed said tasks while sharing their screen via video conference, so that the researcher could monitor their progress. Tests were administered in the same order to all study participants, with a break allowed at the participant's digression in order to minimize fatigue.

3.3 Measures

Gorilla Experiment Builder (www. gorilla.sc) was used to create and host the experiment.

3.3.1 Mathematical skills: TOBANS Arithmetic Subtests

Children's mathematics performance was measured using the arithmetic subtests of the Test of Basic Arithmetic and Numeracy (TOBANS). This consisted of 5 subtests: addition, addition with carry, subtraction, subtraction with carry, and multiplication. The present study is the first to administer TOBANS remotely, as it is currently a paper and pencil test. Images of the online adaptation of TOBANS used in this study can be found in Appendix F.

Remote TOBANS administration differed from the original test in that participants typed their answers rather than hand write them in a test booklet. The instructions, number of math problems in each subtest, and time limits of the original test were maintained in the remote version, with the exception that any instruction in the original test which directed children to 'turn the page' was replaced by saying 'click red button that says 'next''. TOBANS administration consisted of participants completing 3 practice questions before beginning each subtest. Participants were then given one minute to complete as many arithmetic problems as

they could for each subtest. The researcher observed them and verbally notified the participant when time was up. Each subtest was scored such that 1 point was awarded for each mathematics problem correctly solved within the time limit.

Psychometric properties for the TOBANS arithmetic subtests when remotely administered do not yet exist. However, in creating an online version of the test using Gorilla, much of the current paper-and-pencil test's structure and administrative procedures were maintained. Therefore the psychometric properties of the current paper-and-pencil version of TOBANS are presented here. The test developers of TOBANS found it to have very good test-retest reliability, as a sub-sample of 93 children from the original standardization sample re-took the test after a 2 day interval, and reliability of over .85 was found for all arithmetic subtests included in this study (Hulme et al., 2016). The test developers also validated TOBANS against a standardized math achievement test, the WIAT-2 (Wechsler Individual Achievement Test- 2nd UK Edition, 2005), as well as against the 2012 Maths SATS. The TOBANS arithmetic composite scores, which are not used in the analysis for the present study but are calculated using scores from the 5 subtests arithmetic used here, strongly correlated with both the WIAT-2 (r= .81) and the SATS scores from 2012 (r= .72). This indicates good concurrent validity of the arithmetic subtests.

3.3.2 Working Memory: Digit Span

A digit span task was included in the battery because it is a paradigm for working memory skills. This digit span task was a good choice for the present study due to its acceptability as a marker of working memory, as well as its brevity of administration. Imbo and Vandrierendonck (2007) suggest that this is a task in which participants must control attention, and maintain information in a quickly retrievable state, which is also an important skill for math performance. Previous research by Hinton et al. (2004) also showed that digit span performance contributed to academic achievement.

The digit span task used in the present study was adapted from the Gorilla task library. The version of the digit span used in the present study was an online task, since data collection took place remotely. Images of the task instructions as they appeared in our study may be found in Appendix G. Often, the task is administered in-person, where a string of numbers is orally presented, and children must immediately verbally repeat the string of numbers back to the

experimenter. The test was not presented in this way in the present study due to concerns over video conference software potentially lagging, affecting both administration and scoring. Prior to completing the task, participants completed 3 practice trials to ensure comprehension of instructions. Then, participants completed 4 trials in which strings of numbers, flashing one at a time on the screen for 500ms each, were displayed and participants were asked to immediately type the numbers in the same order of presentation. The number of digits in a string increased with each subsequent trial, beginning with a string of 4 digits and progressing to 7 digits on the final trial.

Each child's score was the total of correct responses. Maximum span length, meaning the longest string of numbers they correctly remembered, was also recorded.

A 2022 study also examined the concurrent validity of the digit span administered online and in an in-person laboratory setting, and found that group means on task effectiveness did not differ significantly ($t(39) = -1.24$, $p = .222$, $d = -.39$, Brimmell & Vaughan, 2022). This suggests that the reliability and validity of the task when administered in-person likely does not differ significantly from reliability and validity estimates of the online task in the present study. The digit span task, administered verbally rather than online, was found to have good test-retest reliability in a sample of children ($r = .87$, Gray, 2003). Alloway et al. (2008) established that the digit span subtest of the Wechsler Intelligence Scale for Children- IV (WISC-IV), which is administered verbally as well, had good discriminative validity, as children who scored poorly on the Automated Working Memory Assessment (AWMA) scored significantly lower on digit span than children with average scores on the AWMA ($F[1,63] = 86.59$, $p < .001$).

3.3.3 Inhibition: Go/No Go

A Go/No Go task was used in the present study and was adapted from the Gorilla task library. Images of the task and its instructions as they appeared during data collection may be found in Appendix H. Go/No Go was included with the purpose of potentially tapping into children's inhibition skills. Go/No Go is a continuous performance task (CPT), meaning it is a measure of sustained attention, as well as inhibition (Kropotov, 2016). The version used in this study was one involving simulataneous discrimination, where participants responded by pressing the spacebar whenever a target stimulus appeared on their screen. Prior to completing the task in each condition, participants briefly completed 2 practice sets of 5 trials each in each condition

(10 practice trials in total for each target condition) to ensure the instructions had been understood. During the task, participant's screens began with a 2 x 2 array of stars. A single letter (P or R) was then presented in one of the squares for a duration of 500 milliseconds with an inter-stimulus interval of 1,500 milliseconds (Bezdjian et al., 2009). Each condition comprised 40 trials. The task was completed in two blocks, first with 'P' as the target stimulus and then a reversal condition with 'R' as the target. Inhibiting response to the distractor required inhibitory control, and as such, the 'R' trials were of particular interest as the distractor stimulus was 'P', the previous target stimulus. Thus, 'R Go/No Go' required inhibition of a prepotent response, which prior evidence suggests may be associated with math skills.

Go/No Go was scored such that participants received 1 point for each correct response. For incorrect responses, participants could potentially make either omission or commission errors, with omission errors being a lack of response to the target, and a commission error being a response to a distractor. Commission errors are typically considered as an indicator of inattention to the task, while omission errors are considered as indicators of impulsivity (Barkley, 1991; Halperin et al., 1991). The type of each error on both the 'P' and 'R' block was also recorded.

In a sample of children, the online Go/No Go task was found to have good test-retest reliability (r= .79, Kindlon et al., 1995). However, in a study investigating the psychometric properties of tasks of a Go/No Go application recently developed for use with children, the visual-motor subtest, which most closely matches the Go/No Go task completed by participants in the present study, was found to have poor and nonsignificant convergent validity with the Hayling test, a measure of response inhibition (r =.12; p < .118, Sartori et al., 2021).

3.4 Analytic Strategy

All data analyses were performed by using IBM SPSS statistics, version 28. The alpha levels were set at $p < .05$. Corrected tests for unequal variances were used when appropriate based on Levene's test for equality of variances.

Suitability of the TOBANS arithmetic subtests (addition, addition with carry, subtraction, subtraction with carry, and multiplication) for factor analysis was assessed using a bivariate correlation analysis of the 5 variables. With correlational analyses having satisfactory coefficients between the 5 subtests, factor analysis was used to calculate a latent variable for

TOBANS performance. Bivariate correlation analyses (Pearson's) between all continuous variables were run (Age, TOBANS factor score, digit span score, maximum digit span, P-Go/No Go Score, R-Go/No Go Score, P-Go/ No Go omission errors, P-Go/No Go commission errors, R-Go/ No Go omission errors, and R-Go/No Go commission errors). In order to allow the reader to judge the likelihood of Type 1 errors, we provide 95 % confidence intervals for each correlation coefficient. A two-tailed independent-samples t-test was run to investigate whether participants differ significantly by gender on any measures which were normally distributed. For non-normally distributed variables, a Mann-Whitney U Test was used to compare groups by gender. Finally, a hierarchical mixed-model regression analysis, based on our hypotheses, with maximum likelihood estimation was used to test each hypothesized model explaining variance in TOBANS performance. Analyses were performed for each component of executive function that was relevant to our hypotheses (working memory, inhibition). The order in which variables were added to the regression was based upon the magnitude of correlations observed. Digit span scores were included in Stage 1, then in Stage 2 age was added to the model; in Stage 3 the measures derived from the Go/No Go task were added: Go/ No Go (P and R) scores, and commission and omission errors. Finally in Stage 4, gender was added.

Chapter 4: Results

Descriptive statistics of the sample are shown in Table1, and descriptive statistics for data from the TOBANS subtests, digit span task, and Go/No Go task are summarized by Table 2 (Appendix J). This is followed by data from the TOBANS subtests, digit span task, and Go/No Go task. Next, results of parametric and non-parametric analyses run to address the study's research questions will be presented in tables. The research questions were as follows:

1. Is there a relationship between math achievement and executive functioning?
    a. Is there a relationship between math achievement and a task relating to working memory?
    b. Is there a relationship between math achievement and a task relating to inhibition?
2. Is there a moderating role of gender in the relationship between math achievement and executive functioning?

Table 1. Participant Age by Gender (months)

	n	*M*	*SD*
Female	10	91.9	6.74
Male	18	95.0	6.33
Total	28	93.89	5.53

Table 2. Descriptive Statistics

	n	*M*	*SD*	Min	Max
Addition	28	13.96	6.95	2	30
Addition with carry	27	9.04	5.03	0	19
Subtraction	28	12.57	6.22	3	28
Subtraction with carry	28	7.43	6.03	0	25
Multiplication	28	6.21	5.72	0	17
Digit Span	28	1.11	0.79	0	3
Maximum Digit Span	28	3.68	1.87	0	6
P Go/No Go	28	36.14	3.39	24	40
R Go/No Go	28	35.54	3.80	25	40
P Go/No Go Omission Errors	28	2.86	1.94	0	7
P Go/No Go Commission Errors	28	0.96	2.66	0	13
R Go/No Go Omission Errors	28	3.11	2.18	0	8
R Go/No Go Commission Errors	28	1.32	2.98	0	11

P Go/No Go refers to the first block of the Go/No Go task where P was the target (Go) and R was the distractor (No Go); R Go/No Go refers to the second block of the Go/No Go task where R was the target (Go) and R was the distractor (No Go) as well as the prepotent response to inhibit.

4.1 Factor Analysis- Creating a Latent Variable for TOBANS Performance

Initially, the factorability of the 5 TOBANS Arithmetic subtests was examined (Appendix K). Several well recognized criteria for the factorability of a correlation were used. Firstly, it was observed that all 5 of the subtests correlated strongly and significantly with each other (Table 3). Correlation coefficients ranged from $r = .679$ to $r = .835$, and all correlations were significant at $p < .001$. This exceeds the recommendation that correlations be greater than .3, indicating that there is sufficient commonality to justify comprising a factor (Tabachnick & Fidell, 2001) Secondly, the Kaiser-Meyer-Olkin measure of sampling adequacy was .875, above the commonly recommended minimum value of .6, and Bartlett's test of sphericity was significant ($\chi 2\ (10) = 102.12$, $p < .01$). This indicated that the arithmetic subtests of TOBANS met the commonly accepted criteria for factorability, allowing the use of factor analysis to create a latent variable for TOBANS performance.

Table 3. Descriptive Statistics and Correlation Matrix – TOBANS Subtests

	Variable	*n*	*M*	*SD*	1	2	3	4
1.	Addition	27	14.22	6.94	-			
2.	Addition with carry	27	9.04	5.03	.757**	-		
3.	Subtraction	27	12.74	6.27	.804**	.736**	-	
4.	Subtraction with carry	27	7.56	6.11	.722**	.740**	.835**	-
5.	Multiplication	27	6.44	5.70	.679**	.746**	.727**	.728**

**p<.01

Finally, the communalities were all above .3, further confirming that each item shared some common variance with other items (Table 4). Given these overall indicators, factor analysis was deemed to be suitable with all 5 TOBANS subtests.

Table 4. Communalities

	Factor loading
Addition	.787
Addition with carry	.792
Subtraction	.847
Subtraction with carry	.814
Multiplication	.751

Principal components analysis was used because the primary purpose was to identify and compute a composite score for the factor underlying the arithmetic subtests of the TOBANS. Initial eigen values indicated that a single factor explained 79.82% of variance.

Analyses indicated that there was a single factor underlying 7–8-year-old children's TOBANS performance on arithmetic subtests and that this factor was strongly internally consistent. Therefore, the latent variable for TOBANS performance was deemed suitable for parametric statistical analyses. This latent variable was labelled 'TOBANS Performance' and used in subsequent analyses described below.

4.2 Correlations

Pearson correlation coefficients were computed to determine the relationship between TOBANS performance and digit span scores (number of correct responses) and maximum digit span (highest span correctly recalled), and between TOBANS performance and P Go/ No Go performance, R Go/No Go performance, P and R Go/ No Go omission and commission errors and are summarized in Table 5 (Appendix L).

Table **5**. Correlation **of Executive Functioning Variables against TOBANS Latent Variable**

Variable	*r*	95% CI	
		LL	*UL*
Age	.409*	.035	.683
Digit Span	.451*	.85	.709
Maximum Span	.263	-.130	.585
P Go/ No Go	.214	-1.81	-.549
R Go/ No Go	.139	-.254	.493
P Go/No Go Omission Errors	-.029	-.404	.355
P Go/No Go Commission Errors	-.249	-.575	.145
R Go/No Go Omission Errors	.128	-.265	.485
R Go/No Go Commission Errors	-.290	-.604	.101

*p<.05; P Go/No Go refers to the first block of the Go/No Go task where P was the target (Go) and R was the distractor (No Go); R Go/No Go refers to the second block of the Go/No Go task where R was the target (Go) and R was the distractor (No Go) as well as the prepotent response to inhibit.

Firstly, the results indicate a significant positive relationship between TOBANS performance and age, r= .409 [0.035, 0.683], p= .034. For measures relating to executive functioning tasks, the results indicate a significant positive relationship between TOBANS performance and digit span scores, *r*= .451 [0.85, 0.709], p= .018. However, there were no other significant relationships between TOBANS performance and any measure of Go/No Go performance, nor maximum digit span.

To sum up, the older a child was the higher they tended to score on TOBANS arithmetic subtests. Furthermore, as digit span scores increased, TOBANS performance also increased. This supports the hypothesis that TOBANS performance positively associates with digit span performance, suggesting a relationship between math achievement and working memory task performance. On the other hand, the results do not support any significant relationship between TOBANS performance and Go/No Go task performance, and therefore lack support for the hypothesis that TOBANS performance would positively associate with Go/No Go performance.

4.3 Examining Potential Gender Differences

There were 9 female and 18 male participants. In order to determine whether prticipants differed on any measures by gender, an independent samples t-test was run. Assumptions for suitability for an independent samples t-test was assessed for all independent variables (age, TOBANS arithmetic subtests, P Go/No Go, R Go/No Go, P Go/ No Go omission errors, P Go/No Go commission errors, R Go/No Go omission errors, R Go/No Go commission errors). Based on skewness values (Appendix J), the data was found to not be normally distributed for the following variables: TOBANS performance (latent variable), Addition, Addition with carry, subtraction, Subtraction with carry, Maximum digit span P Go/ No Go, R Go/No Go, and Commission errors (P and R). An independent-samples t-test was conducted to compare TOBANS performance on all subtests besides subtraction with carry, digit span scores, and Go/No Go omission errors between genders (Appendix M). A Mann-Whitney U Test was run to compare means by gender for the non-normally distributed variables (Appendix N).

Table 6. Independent Samples t-test Comparing Means by Gender

	Female		Male		*t*(25)	*p*	Cohen's *d*
	M	*SD*	*M*	*SD*			
Age (months)	91.44	6.98	95.0	6.33	1.33	.196	0.54
Multiplication	5.22	4.97	7.06	6.07	0.78	.442	0.32
Digit Span	0.89	0.60	1.22	0.88	1.02	.317	0.42
P Go/No Go Omission Errors	2.22	1.30	3.17	2.20	1.18	.249	0.48
R Go/No Go Omission Errors	2.33	1.23	3.56	2.50	1.38	.181	0.56

The independent samples t-test comparing male and female participants on Age, Multiplication, digit span, P Go/No Go Omission Errors, and R Go/No Go Omission errors revealed no significant differences. Of the approximately normally distributed variables, there were no significant gender differences.

Table 7. Mann-Whitney U Test Comparing Means by Gender

	Female Mean Rank	Male Mean Rank	*U*	*p*
TOBANS Performance	11.44	15.28	58.0	.253
Addition	10.90	16.50	54.0	.089
Addition with carry	11.56	15.22	59.0	.275
Subtraction	10.80	16.56	53.0	.080
Subtraction with carry	11.85	15.97	63.50	.208
Maximum Digit Span	12.40	15.67	69.0	.332
P Go/No Go	14.30	14.61	88.0	.944
R Go/No Go	15.50	13.94	100.0	.627
P Go/No Go Commission Errors	15.80	13.78	103.0	.555
R Go/No Go Commission Errors	16.15	13.58	106.5	.436

The Mann-Whitney U Test comparing female and male participants on TOBANS performance, Addition, Addition with carry, Subtraction, Subtraction with Carry, Maximum digit span, P Go/No Go, R Go/No Go, and Commission errors (P and R) revealed no significant differences.

In sum, the results of the independent samples t-test and Mann-Whitney U test do not indicate detection of any significant gender differences on any measures of math achievement, working memory, nor inhibition in this sample.

4.4 Hierarchical Regression

In order to determine the degree to which the independent variables account for variance in TOBANS performance, a four-stage hierarchical regression was conducted with TOBANS performance as the dependent variable, which is summarized in Table 6 (Appendix O). The variables entered at each stage of the regression were based on hypotheses of how components of executive functioning could relate to math achievement, based on previous research, as well as informed by correlational analyses and group mean comparisons described in the previous sections. As such, digit span score was included in Stage 1, as it was found to correlate most strongly with TOBANS performance. At Stage 2, age was included in the model, as it also was found to significantly correlate with TOBANS performance. Variables added in Stage 3 all

related to the Go/No Go task, and therefore comprised P Go/No Go scores, R Go/No Go scores, P Go/No Go omission errors, P Go/No Go commission errors, R Go/No Go omission errors, and R Go/No Go commission errors. Gender was added in Stage 4.

Table 8. Hierarchical Regression

Variable	*B*	β	*t*	*R*	R^2	ΔR^2
Stage 1				.451	0.20	0.20
Digit Span	0.56	0.45	2.52*			
Stage 2				0.54	0.29	0.08
Age	0.05	0.30	1.68			
Stage 3				0.61	0.38	0.09
P Go/No Go	0.26	0.90	0.26			
R Go/No Go	-0.57	-2.19	-0.51			
P Go/No Go Omission Errors	0.19	0.37	0.19			
P Go/No Go Commission Errors	0.26	0.71	0.26			
R Go/No Go Omission Errors	-0.57	-1.25	-0.48			
R Go/No Go Commission Errors	-0.65	-1.96	-0.57			
Stage 4				0.63	0.40	0.02
Gender	-0.36	-0.17	-0.74			

*p<.05; P Go/No Go refers to the first block of the Go/No Go task where P was the target (Go) and R was the distractor (No Go); R Go/No Go refers to the second block of the Go/No Go task where R was the target (Go) and R was the distractor (No Go) as well as the prepotent response to inhibit.

The hierarchical multiple regression revealed that Stage 1, digit span scores predicted approximately 20.3% of variance in TOBANS performance and digit span being a significant predictor in the model (β= 0.451, p= .018). In Stage 1, the model was significantly predictive of variance in TOBANS performance (R^2= 0.203, F(1, 25)= 6.368, p= .018). At Stage 2, the inclusion of age revealed a non-significant increase in variance accounted for by the model ((ΔR^2= 0.084; ΔF= 2.83, p= .105). The inclusion of Go/No Go variables at Stage 3 lead to a non-significant increase in variance accounted for by the model (ΔR^2= 0.09; ΔF= 0.43, p= .847). The inclusion of gender at Stage 4 lead to a non-significant increase in variance accounted for by the model (ΔR^2= 0.02; ΔF= 0.55, p= .471). Since gender did not account for significant variance in

TOBANS performance, it cannot be considered a moderator in the relationship between executive functioning and math performance. No variables were significant predictors at stages 2- 4. The overall regression model predicted approximately 39.6% of variance in TOBANS performance (R^2= 0.396, F(1, 17)= 1.24, p= .335).

4.5 Results Summary

The arithmetic subtests of TOBANS were found to be suitable for factor analysis, and as such a latent variable for TOBANS performance was created and used for subsequent analyses. TOBANS performance was found to significantly positively correlate with age and digit span scores. No significant gender differences were found for any of the independent variables. Finally, the hierarchical multiple regressions revealed that only the first stage of the model, with only digit span scores, accounted for significant variance in TOBANS performance, and no subsequent models with age, Go/No Go variables, nor gender were found to account for significant variance. In summary, the results suggest a moderate positive relationship between digit span scores and TOBANS performance, whereby digit span accounts for significant variance in TOBANS performance.

Chapter 5: Discussion

5.1 Interpretation of Findings

The aim of this study was to explore the relationship between math achievement and working memory, with gender as a potential moderator. Statistical analyses sought to investigate whether task performance relating to two distinct components of executive functioning, working memory and inhibition, positively correlated with arithmetic test performance. Additional analyses investigated whether relationships significantly differed across genders, and whether gender moderated the relationship between executive functioning and math achievement. These potential relationships were explored using the TOBANS arithmetic subtests as a measure of math achievement, the digit span task as a measure of working memory, and the Go/No Go task as a measure of inhibition.

With regards to the first research question, findings do support a potential relationship between working memory and math achievement, but not a relationship between inhibition and math achievement. Results indicated a significant positive correlation between digit span task performance and a latent variable for TOBANS performance, and a regression model indicated that digit span task performance accounted for significant variance in TOBANS performance. Therefore, the results do support the hypothesis that working memory relates to math achievement. However, no significant results were revealed with regards to Go/No Go task performance, so the hypothesis that inhibition relates to math achievement is not supported. This is potentially due to issues with the Go/No Go task specifically, as well as challenges measuring inhibition in general.

With regards to the second research question, there were no significant group differences by gender on any measures. Gender did not account for unique variance in TOBANS performance and therefore cannot be considered as a moderator in the relationship between executive functioning and math achievement in the present study. The lack of significant findings relating to gender could potentially be due to the present study's small sample which was unbalanced for gender.

5.2 Factorability of TOBANS Arithmetic Subtests

The present study was the first to adapt the TOBANS Arithmetic subtests for remote administration. Doing so was advantageous as it allowed for collection of a rich volume of data

demonstrating participants' arithmetic math skills within the short timeframe of data collection, without needing the time and resources to administer an in-person paper-and-pencil test. In order to optimally utilize the multiple variables of data which these subtests produced, we conducted factor analysis to produce a single latent variable for TOBANS arithmetic subtests performance.

The strong and significant correlations between subtests bode well for the factorbility of these measures. As TOBANS is a relatively new assessment tool, developed in 2016 (Hulme et al., 2016), the use of its arithmetic subtests as a latent variable in the present study show great promise for its future use as a measure of arithmetic abilities, and its feasibility for remote administration.

5.3 Math Achievement and Working Memory

5.3.1 Relationship between TOBANS Performance and Digit Span

To reiterate the results of the study, the latent variable for TOBANS performance was significantly positively associated with digit span scores, and digit span scores accounted for 20.3% of variance in TOBANS performance. This means children who got higher scores on the digit span task also tended to score higher on arithmetic tests. Based on prior research, digit span performance is a paradigm for working memory skills, so this finding provides support for the existence of a relationship between working memory and math achievement.

One cognitive ability which likely contributed to performance on both TOBANS arithmetic subtests and digit span is processing speed. While processing speed is not itself a component of executive functioning, it has been suggested to impact working memory as well as math cognition (Formoso et al., 2018). TOBANS subtests were timed such that participants had only one minute to complete as many problems as they could within the time limit of each subtest. For digit span, each number in a string was displayed for only 500 milliseconds before the next digit appeared, and thus each digit needed to quickly be encoded and held in short-term memory in order to process the next number, and subsequently retrieve the string immediately after presentation. Sturm et al. (2018) corroborates this in that they found both processing speed and a backwards digit span task to be significantly positively associated with a math computation measure amongst 8-15 year old children. Additionally, it has been suggested that processing speed plays an important role in the relationship between executive functioning and general academic achievement in primary school children, such that processing time within working

memory tasks can be predictive of academic attainment (Gordon et al., 2018). The digit span task utilized in the present study did not allow for investigation of processing speed as other working memory measures do, however using TOBANS arithmetic subtests through online administration could allow for measurement of processing speed for individual math problems within tests, which could be an interesting future direction for exploring processing speed as a potential moderator. Based on the aforementioned prior research by Gordon et al. (2018) and Sturm et al. (2018), it is likely that processing speed may explain the relationship between TOBANS arithmetic subtest performance and digit span performance.

5.3.2 Corroborating Extant Literature About Math and Working Memory

The significant positive association between digit span scores and TOBANS arithmetic subtest performance supports an abundance of prior literature in finding a relationship between working memory and math achievement. Gathercole and Pickering (2001) suggest that the mental workspace provided by working memory is supportive of the cognitive demands placed by mathematical computations. As such, strong working memory resources are thought to promote mental arithmetic ability (Adams & Hitch, 1997). Given the results of prior literature and the present study, it is likely that working memory facilitates math achievement.

One model of working memory posits a central executive with two slave systems, a phonological loop for verbal processing, and a visuospatial sketchpad (Baddeley & Hitch, 1974). The digit span task used here is typically thought to capture the verbal processing element of working memory (Gathercole et al., 2004). However, recent evidence suggests that visuospatial working memory may relate more strongly to math achievement than verbal working memory (Giofrè et al., 2018). Giofrè et al. (2018) demonstrated that working memory paradigms could be identified as relating to either verbal and visuospatial working memory, and along these distinctions had different predictive power in explaining variance in achievement measures of math and reading. Exploring both verbal and visuospatial working memory was beyond the scope of this study, however further investigation of TOBANS performance and working memory tasks of different modalities, including both verbal and visuospatial working memory tasks, would be an excellent future direction to further parse this relationship. Given the association between verbal working memory and math achievement revealed in the results of the present study, it could be hypothesized that math achievement associates with both modalities of

working memory; however based on the work of Giofrè et al. (2018), the strength of association with tasks of visuospatial working memory and math achievement may be greater.

The present study was limited to exploring academic achievement only in the form of math arithmetic skills. However, a plethora of research suggests that working memory relates to other areas of academic achievement in addition to math arithmetic. St Clair-Thompson and Gathercole (2006) found that working memory is strongly associated with math and reading attainment. They postulated that this could be explained by saying that working memory promotes foundational learning skills which are necessary for developing reading and math skills. Further evidence for the importance of working memory for academic learning and achievement can be found in a case study by Gathercole et al. (2006), which closely investigated a small sample of children who had scored very poorly on measures of working memory. Researchers found that the children with poor working memory failed to meet the working memory demands of school activities insofar that they frequently forgot instructions, failed to meet processing and storage demands, lost track of complex tasks, and could not retain long-term episodic memory. This suggests the demand that learning academic content in a school context places on working memory, and as such, the strength of association between math achievement and working memory in the present study is indicative that those children who are best suited to learn because of their good working memory skills, clearly can demonstrate what they have learned in the context of arithmetic measures like TOBANS.

5.4 Math achievement and Inhibition

5.4.1 Relationship between TOBANS Performance and Go/No Go

In the present study, there were no significant results to suggest that there was an association between TOBANS performance and Go/No Go task performance. In the correlation matrices, there were no significant associations between TOBANS and P-target Go/No Go scores, R-target Go/No Go scores (reversal condition), nor omission or commission errors for either task version. The Go/No Go variables also did not account for any significant variance in TOBANS performance. Hence, the results of this study did not support the hypothesis that Go/No Go, a measure related to inhibition, is associated with math achievement.

5.4.2 Dissenting Extant Literature About Inhibition and Math Achievement

Inhibition was hypothesized to be associated with math achievement based on prior literature. Previous studies finding associations between math achievement and inhibitory control suggest that inhibition allows for suppression of inappropriate strategies, and prepotent number representations (Bull & Lee, 2014). For example, difficulty may arise in mathematics when erroneous or pre-existing strategies are activated when children approach a novel math problem type.

St Clair-Thompson and Gathercole (2006) found inhibition to be associated with attainment across curricular areas including English, math, and science, when working memory was controlled. Based on this finding, the authors suggested that inhibition supported learning in general. In a comparison of groups of low and high achieving students on mathematics on measures of working memory and inhibition, significant group differences were uncovered such that high achieving math students outperformed the low achievement group on measures of inhibition (Chamandar et al., 2019). This previous finding indicated a likelihood that having good inhibitory control supported math achievement.

5.4.3 Potential Explanations for the Lack of Association between Inhibition and Math

There are a number of potential reasons why the results of the present study did not support the findings of the prior literature mentioned above. In the context of our study, the Go/No Go task was the final task to be completed in the battery. Therefore, it is possible that participants' performances on this measure were impacted by fatigue, and that this has contributed to the lack of findings. It is possible that children who may have performed well on the TOBANS arithmetic subtests, which were the first to be completed, lacked the mental resources to perform to their full potential by the time they reached the Go/No Go task. If this were the case, then their performance may not have accurately demonstrated their full abilities, which would provide some explanation for why Go/No Go task performance did not correlate with math achievement in this particular study. Perhaps if children who had performed well on the TOBANS arithmetic subtests early in the battery had performed to their full potential on the Go/No Go task, their scores on both measures would have correlated significantly.

Another potential explanation specific to this study was the sample. There is evidence to suggest that associations between inhibition and math skills may be more apparent in clinical samples, such as those with ADHD, or with poor math performance (Dekker et al., 2017). The current study used convenience sampling, and thus did not seek out participants with exceptionally poor abilities on any measure compared with the wider population. Therefore, the lack of findings in our study may support the idea that sample type may be a moderating variable in the relationship between inhibition and math achievement.

5.4.3.1 Flaws of Go/No Go

We solely used Go/No Go as a marker of inhibition, whereas both of the studies discussed in the previous section used other indicators of inhibition. While Go/No Go was selected for this study for its brevity and ease of administration with children, particularly in a remote setting, there is evidence to suggest it is flawed. According to Lee and Lee (2018), the error rate in Go/No Go tends to be very low even amongst children, and requires many trials in order for differences in error rates to be detected. This may have been the case in our study, as there were only 80 trials in all, and evidence to suggest ceiling effects, given that even within the young age group of our sample, 5 children actually made no errors on one or both blocks of the task. Therefore, we suggest that in aiming to select an inhibition measure that was suitable for children, we perhaps selected a measure that was too easy for significant differences to be detected.

5.4.3.2 Challenges Measuring Inhibition

It is of interest that this is not a problem limited to the Go/No Go task, but one which impacts many other measures of inhibition. Several other measures seek to tap inhibitory control by recording and comparing reaction times to prepotent and interfering stimuli, however here also the issue arises that tasks become too easy. In order to compare reaction time, it cannot be too challenging to respond accurately, because there is little to be ascertained from the reaction time of an incorrect response (Lee & Lee, 2019). Tasks which are easy to be accurate on often do not yield detectable differences on reaction times (Lee & Lee, 2019). This leaves researchers grappling with a speed and accuracy trade-off whereby inhibition tasks must be easy enough that participants will answer enough items correctly so that researchers have reaction times to

compare across conditions, but challenging enough that reaction times differ between prepotent and interfering stimuli. In sum, there is an overarching problem of lacking sensitivity in measures of inhibition, including Go/No Go as was demonstrated in the present study, so it is inconclusive whether a significant relationship between inhibition and math achievement would have been found even if a measure other than Go/No Go had been used.

5.4.3.2.1 Misalignment of inhibition tasks and inhibition in math

Lee and Lee (2018) further posit that tasks aiming to measure inhibition may fail to pose the same kind of interference used to succeed in math calculation. They argue that distractions in math problem solving typically take the form of environmental distractors in a classroom setting, and differential knowledge of strategies and heuristics. The former was not measured in the present study as data collection did not take place in a classroom environment, so it could be said that the type of inhibitory control utilized for Go/No Go did not align with the real world inhibitory control children would need to complete math activities in school. As for the latter, Lee and Lee (2018) argued that most inhibition measures require inhibiting task-irrelevant information or distractors based on arbitrary rules set by experimenters, whereas in math problem solving, children's own semantic knowledge is relied upon to identify what strategies or information is not relevant for a given problem. In the Go/No Go task, it was the case that the rules were arbitrarily set, so selective inhibition of previously learned strategies was not a skill required for task performance. This idea from Lee and Lee (2018) therefore suggests that Go/No Go may not have tapped into the same kind of inhibition as TOBANS, thus the lack of significant association.

5.4.3.3 Task Impurity in Executive Functioning Tasks

This problem extends beyond inhibition tasks to task impurity of executive functioning tasks in general. In a review by Bull and Lee (2014) exploring relationships between math achievement and inhibition and shifting, multiple studies were referenced as having observed small amounts of variance attributable to executive functioning in any one executive functioning task (Lee et al., 2013; Willoughby et al., 2012). It is not recommended to rely on a single task to measure a construct. However, time constraints for data collection in the present study did not allow for multiple measures of inhibition in the assessment battery. Using only one task limits

differentiation of one executive function from another, as realistically a task that distinctly relies on one component and no other would be very challenging to develop (Bull & Lee, 2014). It is likely that Go/No Go was not "pure" in the sense that other executive functions besides inhibition were implicated in completing it. As such, this was another weakness of our study design and provides another explanation for why significant results were not revealed regarding the relationship between inhibitory abilities and math performance.

5.4.4 Corroborating Extant Literature About Math and Inhibition

In the same review by Bull and Lee (2014), two confirmatory factor analysis studies (Lee et al., 2012; Van der Ven et al., 2012) did not find inhibition to be predictive of math performance. Based on the tasks by which inhibition was measured in these studies, and compared to how it has been examined in past studies which did find an association with math skills, Bull and Lee (2014) suggest that a potential explanation for this could be that inhibition and mathematics may only relate when inhibitory tasks minimally involve memory load and do not include rule switching. In the present study, the Go/No Go task did include rule switching, so our findings concur with those of the studies reviewed by Bull and Lee (2014).

It is possible that only under specific circumstances can an association between inhibition and math achievement be found. However, issues with inhibition measurement tools, as well as overall task impurity in executive functioning measures present challenges for researchers investigating this association. The lack of findings in the present study lends support to the implications put forth by Lee and Lee (2019): that there is a need for inhibition tasks which target the sort of interference children might experience in a classroom setting when practicing mathematics. Overall, previous literature suggests an inconsistent relationship between math achievement and inhibition, and this study further demonstrated this.

5.5 Gender, Math Achievement, and Executive Functioning

5.5.1 Relationship between TOBANS Performance, Executive Functioning Tasks, and Gender

Our results revealed no significant gender differences on TOBANS performance, digit span, nor Go/No Go measures. Gender was not found to account for variance in TOBANS

performance and therefore cannot moderate the relationship between math achievement and executive functioning measures.

There is evidence suggesting that there is a greater prevalence of ADHD in boys than girls. ADHD symptoms correlate with executive functioning, and there is evidence of academic difficulties among children with ADHD. Therefore, it was hypothesized that gender would be a moderator. It was expected that of participants with poor executive functioning, boys would outperform girls on math achievement because they are more likely to have had treatment in some form for their executive functioning difficulties, whereas based on findings by (Klefsjö et al. (2021), girls may struggle with emotional disorders which limit their ability to achieve high scores on measures of academic attainment. However, in comparing group means of male and female participants, it was revealed that they did not differ significantly on any measures in our study.

5.5.2 Potential Reasons for Lack of Results Regarding Gender: Unbalanced Gender Sample

The original sample of our study consisted of 28 children, 10 girls and 18 boys. One girl was excluded from analyses, as her results were invalidated for one of the TOBANS arithmetic subtests. Thus, the final sample for analysis purposes contained only 9 girls and 18 boys, meaning girls comprised just 33% of the sample. This was not ideal for several reasons.

The first reason why our gender imbalanced sample was problematic is the limitations it posed to our analyses. It is firmly rooted in statistical theory that in order to make accurate comparisons across genders, a sample that is 50% female is best as it reflects the gender balance in the wider population. With such a small sample with a higher proportion of male participants, it becomes statistically less likely that significant differences could be detected.

The gender imbalance in this sample was also a disadvantage because, though it occurred by chance, it was imbalanced in the same direction as many other studies that have examined these variables. In ADHD research, boys are overrepresented, leaving much unknown about the disorder in girls (Hinshaw et al., 2022). This has led to issues in the field of ADHD research whereby the subtypes of ADHD are based on commonalities amongst profiles of males with ADHD, and therefore less is known about the expression of the disorder. Unfortunately, this study had too small of a sample, as well as too few female participants to make any relevant

contribution to the literature regarding how gender may play a role in the relationship between executive functioning and math achievement.

5.5.3 Situating Findings within Extant Literature on the Relationship between Gender, Math Achievement and Executive Functioning

5.5.3.1 Dissenting Extant Literature About Gender

The results of the present study do not align with those of a meta-analysis by Cortés Pascual et al. (2019) which investigated the relationship between executive functions and academic performance in primary school education. In their review, a number of studies found gender to be a moderator for executive functions, and their meta-regression revealed gender to account for 49% of variance in the relationship between executive functioning and academic achievement. It was also found that across studies, female participants outperformed males, which the authors explained as an effect of earlier and more rapid maturing of girls from ages 7-12. Given this explanation, it is possible that had the present study sample included a wider age range, gender effects may have been detected, as older children may differ more as they progress in maturity at different rate by gender.

5.5.3.2 Corroborating Extant Literature About Gender

The present study lacks sufficient evidence to draw conclusions regarding the role of gender in the relationship between executive functioning and math achievement. While the previous subsection provided support for gender differences in these variables, there is also evidence from previous literature suggesting that gender differences do not exist.

In their review, Grissom and Reyes (2019) found that among typically developing children, gender differences in executive functions could not be consistently revealed longitudinally. Among 8-10 year old children, Barnett et al., (2007) did find that girls outperformed boys on measures of inhibition, however Lange et al. (2014) found the opposite to be true among adolescents. This demonstrates the inconsistency of findings and lack of long-term gender effects. Similarly, León et al. (2014) failed to find significant gender differences on a working memory task in a gender balanced sample of 100 4-10 year old children. These findings suggest that despite ADHD and gender being associated in previous literature, findings relating gender to executive functioning seem to be inconsistent at best.

In regards to math skills, gender differences are inconsistent across sources as well. Statistics from the National Center for Education Statistics, reporting the achievement of 4th grade students on the National Assessment for Educational Progress (NAEP) Basic Math Achievement standardized test, found male scores to be significantly higher than female scores in 2019, which is the most recent year data was available (National Center for Educational Statistics, 2019). Though significant, the mean score difference between genders was 3, with a mean score of 242 for males and 239 for females. However, a review by Hyde & Mertz (2009) found no significant gender differences in math performance across the studies investigated. The results of an earlier meta-analysis concur that no significant gender differences were detected in elementary school children on complex problem solving (Hyde et al., 1990). Additionally, a study reported effect sizes for gender differences on math standardized assessments to be negligible (d< 10) for all grade levels 2- 11 (Hyde et al., 2008). These previous findings paint a picture of minimal if any differences by gender on math achievement among typically developing children.

The lack of significant gender differences found in the present study therefore align with a large body of literature with similar uncertain findings, however, we lack sufficient evidence to say whether gender similarities would have held within groups with significantly poorer executive functioning. The aforementioned literature which demonstrated inconsistent gender differences on math achievement did not account for differences in executive functioning. Therefore, we recommend continued investigation of a moderating role of gender in the relationship between math achievement and executive functioning in a larger sample which is gender balanced in future research.

5.6 Limitations of the Present Study

5.6.1 Time Constraints

5.6.1.1 Recruitment and Data Collection Timeline

This study was completed as part of a one-year MSc education course, and therefore was on a constrained timeline. Recruitment of participants for this study began in early May 2022, with the first participants' data collection sessions starting in mid-May 2022, while recruitment continued simultaneously. Data collection and recruitment had to be completed by the end of June 2022 in order to allow for sufficient time to analyze results and write this dissertation. Had

data collection carried on for longer than 2 months, it is likely a larger sample size could have been achieved, with a potential for findings of greater statistical power.

5.6.1.2 Data collection session design

In designing the testing battery and data collection procedures, much consideration was lent to the duration of data collection. As was previously mentioned, multiple measures for each construct would have yielded more accurate representations of children's actual executive functioning abilities in the data. However, it was also considered that a longer time commitment for a data collection session, or multiple data collection sessions, might have been a deterrent to families considering enrolling their child as a participant. These concerns needed to be balanced in order to secure a large enough sample size with enough data for use in analysis, hence why the testing battery contained just one measure relating to each construct (math achievement, working memory, inhibition). This resulted in a testing battery which took 30 minutes to administer to each participant.

5.6.2 Recruitment from afar

The principal investigator of this study was based in the United Kingdom while completing this study, however all the participants and their families were located in the United States. This posed some challenges as far as recruitment goes, because information about the study was primarily circulated electronically. Being located in a different country than participants also prevented partnering with a school for recruitment of participants. It is possible the sample size was constrained due to the limitations of recruitment methods this posed.

5.6.3 Representativeness

Data on participants' race and socioeconomic status were not collected. However, in using a convenience sample, it is likely that participants may have had similar demographic characteristics. Thus, it cannot be said that diversity of participant demographics were reflective of the wider population. Additionally, the sample included children living in the United States. Therefore, we caution against concluding that any findings in the present study are reflective of a sample representative of the population.

5.6.4 Challenges of conducting remote research

Conducting remote research had some benefits, as will be discussed in the subsequent section, however it also presented many challenges which may have impacted the results.

Carrying out research remotely relied on participants and their families having access to technology, as well as participants having some familiarity with using a computer. For the former, it is of note that this condition meant that the sample was made up entirely of children whose families had computer access, usually in the home, and therefore the sample may not be representative of children from low socioeconomic backgrounds who may be less likely to have access to technology. As far as the latter, it was noted that the amount of experience using technology among the children varied, and in some cases may have impacted their task performance. The data which was excluded from analyses had to be due to the child making a technological error in which she exited the browser window after completing a subtest, but before clicking to the next page, so her responses were not saved. Many other children were observed as having difficulty using the computer, especially during the TOBANS tests. Each subtest of TOBANS was made up of between 60 and 120 problems, all on one page. Navigating the page proved a challenge for some children, as they were required to find and use the 'tab' key or move their mouse in order to navigate to the response box for each problem. Despite familiarizing this skill with an untimed practice test before each timed subtest began, several children made errors and spent several seconds not solving problems, and instead trying to scroll or click the box in order to type their next response.

The assessment of executive functioning and math skills in an individual and online setting may also limit our findings in that it is not reflective of a real-world setting in which children exhibit their executive functioning and math skills. The classroom is a much more typical place for students to learn and practice math. Additionally, being in a classroom likely differentially taxes executive functioning resources than in an online, individual, and experimental setting like that of data collection for this study. The classroom requires students to inhibit environmental distractions, which were minimized by conducting data collection on an individual basis, as well as providing participants' families with instructions to ensure children were in a quiet space away from others when completing the study. This was necessary in order to maintain a similar setting across participants for data collection. However, it also means that

participants' real-world abilities in math achievement and executive functioning may not have been accurately measured in this way.

5.7 Strengths of the Present Study

Conducting research remotely offered several advantages as well. Using Gorilla Experiment Builder (gorilla.sc) as an experiment authoring and deployment platform made this study accessible both to build as an experimenter, as well as to use for data collection with participants on any computer and with any browser (Anwyl-Irvine et al., 2020). It also meant that the present study could be replicated, as the exact measures used here are publicly available in Gorilla's task library. Utilizing Gorilla also allowed the opportunity to create the first online version of the TOBANS arithmetic subtests. Until now, TOBANS had only been administered in paper-and-pencil test booklets, and typically was designed for classroom administration. This study demonstrates the feasibility of administering the measure online, and using a video conferencing platform to monitor children's adherence to time limits on each test. Finally, conducting research online was a viable alternative to the experimenter traveling and conducting data collection in person. It allowed for more flexibility as to who could participate and when.

5.8 Future Directions

The current study did not find many significant results, and this was likely largely attributable to the small sample size, gender imbalance, and singular measure for each of the constructs studied. Therefore, we recommend future researchers explore a similar research question while recruiting a larger sample that is balanced for gender. Additionally, utilizing multiple tasks relating to each math achievement, working memory, and inhibition would be advantageous. This would allow for the recommended strategy of using factor analysis to create a latent variable for each construct, which would serve as a more pure measure and decrease the measurement error of using a single task (Miyake & Friedman, 2012). Additionally, given the evidence from Sturm et al. (2018) of the potential moderating effect of processing speed in the relationship between working memory and math achievement, it is recommended to include a measure of this variable in future research to allow investigation of this effect. An additional future step would be differentiating between performance on tasks of verbal and visuospatial

working memory, as there is some previous evidence to suggest they may differentially relate to math achievement.

5.9 Conclusion

The current study contributes to the existing body of literature by replicating the findings of previous research in finding a relationship between working memory and math achievement in 7-8 year old children while using a relatively new measure of math achievement, the TOBANS arithmetic subtests. The TOBANS arithmetic subtests were found to be a good fit for a single factor latent variable, indicating the subtests measure an underlying construct of arithmetic abilities. Insignificant results were revealed relating to the relationship between inhibition and math achievement as measured by TOBANS performance. The same was the case for results of gender differences in math achievement and executive functioning tasks. The findings of this study highlight the strength of the relationship between working memory and math achievement. While more work on this topic is needed to fully understand the relationships between these constructs, this study contributes to the emerging picture of potential measures for each construct and indicates which relationships should be investigated further in future research.

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Appendices

Appendix A. CUREC Form (1A)

Central University Research Ethics Committee (CUREC)

CUREC 1A Form for Application form for research projects in the social sciences and humanities with less complex ethical issues

The University of Oxford places a high value on the knowledge, expertise, and integrity of its members and their ability to conduct research to high standards of scholarship and ethics. The research ethics review process has been established to ensure that research involving human participants is conducted in a way that respects the dignity, rights, and welfare of participants, and minimises risk to participants, researchers, third parties, and to the University itself. It is assumed that all members of the University will take their responsibilities and obligations seriously, and will ensure that their research involving human participants is conducted according to established principles and good practice in their field and in accordance, where appropriate, with legal requirements.

Before completing this form, please refer to the guidance and flowchart on the Research Support website. Only type-written forms form will be accepted. Completed application forms should be emailed, along with relevant supporting documents, to your Departmental Research Ethics Committee (DREC) or to ethics@socsci.ox.ac.uk from your ox.ac.uk email address.

Please contact your DREC or the SSH IDREC if you have any questions about completing this form or the review process.

SECTION A: Filter for CUREC 2 application		
This section determines whether the application for ethics review should be made using this form (CUREC 1A) or the CUREC 2 form (for research with more complex ethical issues).		
Please indicate with an 'X'.	**Yes**	**No**

1. Does the research involve the deception of participants?	☐	X
2. Are the research participants vulnerable in the context of the research, or classed as people whose ability to give free and informed consent is in question? For example, ● Participants aged 16 or under (also answer question A5); ● Participants aged 16 – 18 (refer to competent youths for guidance); ● adults at risk; Note the University's Safeguarding Guidance and Code of Practice and its implications for researchers involving young people or adults at risk.	X	☐
3. By taking part in the research, will participants be at risk of criminal prosecution or significant harm?	☐	X
4. Does your research raise issues relevant to the Counter-Terrorism and Security Act (the Prevent Duty), which seeks to prevent people from being drawn into terrorism? Best Practice Guidance 07 on the Prevent Duty provides further guidance.	☐	X
If you answered **'No'** to all the questions above, go to Section B. If you answered **'Yes'** to any question above, continue to question 5 below.		
5. Is your project covered by a CUREC Approved Procedure?	X	☐
If yes, list the CUREC Approved Procedure(s) you will follow	AP25	
If you answered '**Yes**' to ANY of questions 1-4, and answered '**No**' to question 5, **stop** completing this form and do not submit it for ethical review. You will instead need to submit a CUREC 2 application form. If you answered '**Yes**' to **any** of questions 1-4, and your project is covered by an Approved Procedure, **go on to Section B**. If more than one Approved Procedure applies, contact the SSH IDREC or your DREC for advice on whether a CUREC 2 form should be submitted instead.		

SECTION B: Researchers	
1. Name of Principal Investigator or student's supervisor	
2. Department or Institute	Education
3. University of Oxford email address	

Copy and paste the following six rows as necessary to complete for each additional researcher who will be involved in this study, including student(s) and those external to the University.		
4. Name of researcher or student		
5. Department or Institute	Education	
6. University of Oxford email address		
7. Role in research	Student	
8. Degree programme, if student research	MSc Education	
The whole research team		
9. Have the researchers undertaken research ethics and integrity training?	**Yes** X	**No** ☐
10. Please provide details of any research ethics and integrity training undertaken, including the dates of the training. Alternatively state relevant research experience.	Training completed 28/01/2022	
11. State any conflicts of interest and explain how these will be addressed.	N/A	

SECTION C: The research project	
1. Title of the research project	
The Relationship between Executive Functioning Skills and Mathematical Performance: A Cross-Sectional Correlation Study	
2. Anticipated start date of the aspect of the research project involving human participants and/ or personal data (**dd/mm/yy**).	**31st March 2022**
3. Anticipated research end date (**dd/mm/yy**).	12/08/2022
4. Provide a brief lay summary of the aims and objectives of the research. This should cover the questions it will answer and any potential benefits. (max 300 words)	

The aim of this study is to investigate the relationship between performance on two measures of executive functioning, a response inhibition task and a working memory task, and a mathematical performance measure in the form of a math fluency test, in 7–8-year-old students. The primary research question is "What is the relationship between executive functioning task performance and mathematical performance?" and the secondary research question is "Is gender a moderator in the relationship between executive functioning task performance and mathematical performance?" Participants will complete two executive functioning tasks focusing on working memory, response inhibition and attention as well as a measure of arithmetic skills. The subsequent analysis would compare scores to investigate whether gender is a moderator in the relationship between EF and mathematical performance.

5. Please indicate the methods to be used (indicate with an '**X**'):	
Analysis of existing records	☐
Snowball sampling (recruiting through contacts of existing participants)	X
Use of casual or local workers e.g. interpreters (refer to guidance in BPG 01: Researcher safety)	☐
Participant observation	☐
Covert observation	☐
Observation of specific organisational practices	☐
Participant completes questionnaire in hard copy	☐
Participant completes online questionnaire or other online task (refer to guidance in BPG 06: Internet-mediated research)	X
Using social media to recruit or interact with participants (refer to guidance in BPG 06: Internet-mediated research)	☐
Participant performs paper and pencil task	X
Participant performs verbal or aural task (e.g. for linguistic study)	☐
Focus group	☐
Interview (refer to guidance in BPG 10: Conducting research interviews)	☐
Audio recording of participant (you will generally need specific consent from participants for this)	☐
Video recording of participant (you will generally need specific consent from participants for this)	☐

Photography of participant (you will generally need specific consent from participants for this)	☐
Others (please specify below)	☐

6. Provide a brief summary of the research design and methods. What will research participants be asked to do? (max 300 words)
   Please also submit a copy of the questions participants will be asked, if applicable, or some information about the sorts of topics that will be covered.

The proposed study is a correlational design. Two measures of executive functioning, the Digit Span and Go/No Go tasks, as well as the Arithmetic subtests of the TOBANS, will be in a correlation analysis with a latent variable for executive functioning.

In the remote video call with both the child and their guardian, the experimenter will send the participant a link to the Gorilla software experiment builder, via the chat function of the video conference. The experimenter will provide instructions of how to share screen and click the link, so that the child's progress may be monitored. The experiment built with Gorilla will include answering a brief set of questions affirming that they understand the project (see "Child Script – Assent Form" attachment).

The child will then complete the Go/No Go and the digit span tasks in Gorilla. The Go/No Go task is a measure reliant on response inhibition. It involves target and non-target stimuli being presented on screen, and participants must respond (i.e. press the space bar) when a target stimulus appears, and inhibit responding when a distractor is presented. The digit span task is a behavioral measure of working memory capacity, in which participants are presented a sequence of numbers and must repeat back the sequence in order.

Following completion of these brief executive functioning tasks, the participant will be offered an optional 5-minute break.

Following the optional break, the experimenter will explain the TOBANS structure to the participant, then administer the arithmetic subtests of the TOBANS, which have been adapted for remote administration. The TOBANS is a set of subtests measuring basic math fluency. The addition, addition with carry, subtraction, subtraction with carry, and multiplication subtests will be used, and each test requires that participants carry out as many of the presented calculations as possible within a one- minute time limit.

7. List the location(s) where the research will be conducted, including any other countries.	United States of America		
8. Clarify which parts of the research will be conducted in-person and which will take place remotely, e.g. online.	All parts to be conducted remotely		
9. If your research involves fieldwork or travel and your department requires a travel risk assessment, will you have completed and returned a risk assessment form beforehand? Please indicate with an '**X**'. (This must be approved by your department before you travel. If you are travelling overseas, you are advised to take out University travel insurance.) Refer to guidance available from your Department, the Safety Office, the Social Sciences Division, and the Humanities Division, and on travel for University business.		Yes	☐
		No	☐
		Not required in this instance	X
10. In the case of international or collaborative research, explain how you will address any ethical issues specific to the local context. Please provide details of the local review, approval or permission obtained or required. Refer to the BPG 16: Social science research conducted outside the UK. If there will be no local review, explain why not. Please mention any stakeholder or community engagement that has been/ will be undertaken in relation to the research Please also address any physical or psychological risks for Oxford researchers and local fieldworkers in Section G.			
There will be no local review on account of Section 4c of BPG 16, which states the special consideration given to straightforward short-term projects. In this case, the sample size is not large, and the checklist of considerations in the BPG 16 Appendix have been reviewed. There is no fieldwork involved, as data collection will be conducted remotely. The participants will be located in the United States, which is where the researcher is from, and therefore there exists an understanding of the cultural context, and both participants and researcher are native English speakers.			
11. Name of departmental/ peer reviewer (if applicable)	N/A		
12. External organisation funding the research and grant reference (if applicable)	N/A		

13. Please refer to the CUREC Best Practice Guidance and list any that have been used to develop your research.	BPG16

SECTION D: Recruitment of research participants		
1. Number of participants	26	
2. How was the number of participants decided?	Power analysis based on 'Examining the indirect effects of kindergarteners' executive functions on their academic achievement in the middle grades of elementary school' (Nakamichi, N., Nakamichi, K., & Nakazawa, J., 2021)	
3. Age range of participants	7-8 years	
4. Inclusion criteria	Aged 7-8 years old Fluent in English Enrolled in school Normal or corrected to normal vision No hearing impairments	
5. Exclusion criteria	<7years old 9+ years old Not fluent in English Not enrolled in school Significant visual impairment Significant hearing impairment	
6. Indicate with an '**X**' all intended recruitment methods **Please submit copies of the recruitment material that will be used, e.g. advertisement text, introductory email text.**	Poster advert	X
	Flyer	☐
	Email circulation	X
	Social media (e.g. Twitter, Facebook)	☐
	Website	☐
	In-person approach	☐

	Snowball sampling	X
	Recruitment sites (e.g. Mechanical Turk)	X
	Existing contacts or volunteer database	X
	Other (please specify):	☐
7. How will potential participants be identified and approached?	Contacts of the researcher in the United States will circulate the study information poster via email to parents/guardians of eligible children. Parents/guardians interested in volunteering their child as a participant may use the contact information listed on the advert to reach out to the researcher to seek further information. Upon contacting the researcher, they will be sent the participant information sheet to review (see attachment), and a link to opt in to the study and to sign up for an appointment time to meet with the researcher along with their child, and ask any questions about the project.	
8. Will informed consent be obtained from the research participants or their parents/ guardians? If not, please explain why not.	Written informed consent will be obtained from parents/guardians of participants ahead of data collection. Additionally, assent of participants will be obtained.	
9. For each activity or group of participants, explain how informed consent will be obtained from the participants themselves and/ or their parents/ guardians, if applicable. How will their consent be recorded?	Informed consent of participants' parents/guardians will be obtained prior to collecting research. Parents/guardians who express interest in their child's participation will be sent the participant information sheet via email to be reviewed on their own time. Along with it, they will be sent a link to a Qualtrics form where	

Please submit copies of all participant-facing materials for review. E.g.: ● Recruitment material (e.g. emails, posters) ● Information for participants to read (or hear) before they agree to take part (e.g. written information or, if applicable, an outline oral information script). ● A document to record informed consent. Further guidance and templates.	they will be asked whether they consent to their child's participation. If they consent, they will be asked to select a virtual appointment time to meet with the researcher along with their child for their child's data to be collected. Participants and their families will meet virtually with the experimenter via video conference at the time selected by the participant and their parent/guardian. In said virtual meeting, the experimenter will read a scripted explanation of the study to the participant and their parent/guardian. The first page of the Gorilla experiment for the participant will ask the participant short yes/no questions to clarify that they understand the project and wish to participate. This will serve as assent of the participant.
10. Provide details of any payments and incentives and the rationale for providing these. Further guidance in Best Practice Guidance: 05 Payments and incentives in research.	N/A
11. Describe how participants ● may withdraw from the study ● may withdraw any personal information they have provided from the study State any limits to withdrawal, for example once the data has been anonymised or at some other specified stage prior to publication. Make sure participants are aware of any withdrawal limits.	The participant information sheets will state that participants may stop at any point during the study and will not be penalized in any way, and their data will not be collected. Furthermore, the process of obtaining the participants assent will include telling the participant that no one will be upset with them if they decide to stop at any time.

	Participants and their parents/guardians may request that their scores be withdrawn from the dataset up until the date of submission of the dissertation.

SECTION E: Research data

All information provided by participants is considered research data for the purpose of this form. Any research data from which participants can be identified is known as personal data; any personal data which is sensitive is considered special category data. Management of personal data, either directly or via a third party, must comply with the requirements of the UK General Data Protection Regulation (UK GDPR) and the Data Protection Act 2018, as set out in the University's Guidance on Data Protection and Research.

In answering the questions below, please also consider the points raised in the Data Protection Checklist and Data Protection Screening Assessment and whether, for higher-risk data processing, a separate Data Protection Impact Assessment may also be required for the research. Advice on research data management and security is available from Research Data Oxford and your local IT department. Advice on data protection is available from the Information Compliance team.

For guidance on conducting internet-mediated research, refer to CUREC's Best Practice Guidance 06: Internet-mediated research.

1. What data will be collected? (Indicate with an '**X**')

Screening documents	☐	Task results (e.g. questionnaires, diaries)	X
Consent records (e.g., written consent forms, audio-recorded consent, assent forms)	X	IP addresses (refer to Best Practice Guidance 09: Data collection, protection and management for guidance)	☐
Contact details for the purpose of this research only	X	Field notes	☐
Contact details for future use (guidance)	☐	Photographs	☐

Opt-out forms	☐	Information about the health of the participant (including mental health)	☐
Audio recordings	☐	Previously collected (secondary) data	☐
Video recordings	☐	Data already in the public domain. Specify the source of the data:	☐
Transcript of audio/ video recordings	☐	Other, please specify:	☐

2. During the course of the research, where will **each type of** research data be stored?	Data to be collected from participants includes age, gender, and test scores from the arithmetic test, and executive functioning tasks. This data will be stored in Nexus 365 OneDrive for Business, which has been approved by the University's Information Security team for the storage of research data. Per University Policy, this anonymized data must be stored for 3 years following publication. Participants' and their parents/guardians' names and email addresses will be collected for the purpose of communicating about study information and arranging the remote assessment session. Once data collection has been completed, these contact details and communications will be destroyed. Each participant's date of birth will be collected for the purpose of calculating their age at the time of data collection in completed months. DOB information will also be destroyed once participants' ages have been recorded, so that the dataset contains only fully anonymised data. Potentially identifiable information including consent forms with participants and their parent/guardian's names will be protected by whole disc encryption and stored in Nexus 365 OneDrive for Business, and will be destroyed when the research is completed. Participants will only be identified by an anonymous unique identifications number. A record of the participants' names and their

	associated identification number as it appears in the data set will be recorded on a hard copy document and stored in a locked filing cabinet in the Department of Education until research has been completed. Upon completion of the project, these documents will be destroyed via shredding.		
3. Who will have access to the research data during the project?	The researcher and their supervisor will have access to research data. The supervisor will only have access to the anonymized dataset. Participants will not be identifiable from the data. No third parties will have access to the data.		
4. Please complete this section if your research involves the use of secondary (i.e. previously collected) data.	**Please indicated with an 'X'.**	**Yes**	**No**
	Are data access agreements in place for access to and use of this secondary data? (If so, please attach these.)	☐	☐
	Did the individuals agree that their data could be used for this purpose?	☐	☐
	Could anyone (including members of the research team) link the data back to an individual or individuals? If this is a possibility, please explain how the associated ethical issues will be addressed:	☐	☐
5. How do you intend to share the research data at the end of the project?	Depositing in a specialist data centre or archive	☐	
	Submitting to a journal to support a publication	☐	
	Depositing in an institutional repository	X	
	Dissemination via a project or institutional website	☐	
	No plans to share the data	☐	
	Other (please specify):	☐	
6. How do you intend to report and	Thesis publication	X	
	Publication in a peer reviewed journal	X	

disseminate the results of the research? (Indicate with an 'X')	Publicly available report	☐
	Conference presentation	X
	Publication on a website	☐
	Pre-registration	☐
	Report to a research funder	☐
	Providing participants with a lay summary of the results	X
	Submission for academic assessment	☐
	Other (please specify):	☐

7. Explain what will happen to the data at the end of the research project. This question must be answered for each type of data, including completed consent forms.
At the end of the research project, research data (not personal data) will safely be stored for 3 years after final publication. Personal information, including records of participants names and associated identification codes, will be destroyed via shredding upon completion of the project. Following the researcher's departure from Oxford, the anonymized dataset will be held securely by her supervisor for the remainder of the 3-year period.

SECTION F: Protection of research participants and their personal data		
1. How identifiable will the participants be from the **research outputs**? (Indicate with an 'X')	Directly identifiable from the information included	☐
	Pseudonymised/ indirectly identifiable	☐
	Not identifiable – data is anonymous	X
	Other, please specify:	☐
2. To what extent will the **data** be de-identified? How identifiable will any individuals be from the research data?	The data will be full anonymized. The only information stored in the dataset will be participant's gender, age in completed months, and assessment scores, along with a unique identification number. They will not be able to be identified from this information.	

Describe any measures you will take towards assuring confidentiality, potential risks to confidentiality.	Participants' date of birth will be recorded initially for the purpose of calculating their age at the time of data collection, however this will be destroyed upon entering their age into the data set. A record of participants' names and associated identification number will be kept in paper form in a locked filing cabinet in the Department of Education. This will be destroyed via shredding once the project is complete.
3. How will you ensure that third parties (e.g., interpreters and transcribers) are aware of and adhere to the measures described in this form?	No third party will have access to the dataset.

SECTION G: Risks and benefits of the research
1. Will the research involve topics that could be considered sensitive? If so: a. Please provide more detail or supporting information (such as the interview questions) to show the range of questions; b. Explain what steps will be taken to reduce risk of distress; c. Consider seeking advice from within your Department or from the ethics committee including whether the application might benefit from additional ethics review (e.g., via a CUREC 2 application).
The research will not involve topics that could be considered sensitive. The only personal data collected will be participants' ages and genders, and their scores on measures of executive functioning, and mathematical performance
2. Describe any additional burden or risks to the participants and the steps you will take to address these.

N/A
3. Describe any physical or psychological risks to the researcher(s) (including local fieldworkers or research assistants) and the steps you will take to address these.
N/A
4. Describe any benefits of the research, both to participants and to others.
There are no immediate benefits for people participating in this project, however it is the hope of the researcher that this project will lead to a better understanding of the profile of young learners' attentional abilities, and how they relate to mathematical performance.
5. Give details of any other ethical issues or relevant information.
N/A

SECTION H: Professional guidelines		
Please indicate with an '**X**' at least one set of professional guidelines you will follow.		
Research specialism/ methodology	**Association and guidance**	
Anthropology	Association of Social Anthropologists of the UK	☐
Computer Science	ACM Code of Ethics and Professional Conduct	☐
Criminology	British Society of Criminology Statement of Ethics	☐
Education	British Educational Research Association Ethical Guidelines for Educational Research	X
Geography	American Association of Geographers Statement on Professional Ethics	☐
History	Oral History Society of the UK Ethical Guidelines	☐

Internet-mediated research	Association of Internet Researchers Ethical Guidelines British Psychological Society: Ethics Guidelines for internet-mediated research Association for Computing Machinery Code of Ethics and Professional Conduct	☐
Management	Academy of Management Code of Ethics	☐
Political Science	American Political Science Association (APSA) Guide to Professional Ethics in Political Science	☐
Politics	Political Studies Association. Guidelines for Good Professional Conduct	☐
Psychology	British Psychological Society Code of Ethics and Conduct	☐
Social research	Social Research Association: Ethical Guidelines	☐
Socio-legal studies	Socio-Legal Studies Association: Statement of Principles of Ethical Research Practice	☐
Sociology	The British Sociological Association: Statement of Ethical Practice	☐
Visual research	ESRC National Centre for Research Methods Review Paper: Visual Ethics: Ethical Issues in Visual Research	☐
Other professional guidelines		☐

SECTION I: Endorsements and signatures

Please ensure this form is endorsed by the Principal Investigator (or student's supervisor), the Head of Department (or nominee) and, if student research, by the student themselves.

The SSH IDREC Secretariat accepts either option below. If you have a DREC, check which signature option it prefers.

- **Option 1: direct email endorsements**

  Each of the signatories should submit an email from a University of Oxford email address, indicating their acceptance of the responsibilities listed below.

- **Option 2: signatures**

  Please scan the signed form and email it to us as a PDF. Pasted images of signatures cannot be accepted.

Endorsement by the Principal Investigator/ student supervisor and student, if applicable	
I/ we the researchers understand my/ our responsibilities as Principal Investigator (and student, if applicable) as outlined in the guidance on the CUREC website. I/ we declare that the answers above accurately describe the research as presently designed, and that the ethics committee will be informed of any changes to the project which affect the answers to this form. I/ we will inform the relevant IDREC if the Principal Investigator changes.	
Name of Principal Investigator	
Principal Investigator's signature	
Date	
Name of student (if applicable)	
Student's signature	
Date	03/03/2022

Departmental endorsement – from the Head of Department or nominee (Another senior member of the department may sign where the head of department is the Principal Investigator, or where the Head of Department has appointed a nominee. Example nominees include Deputy Head of Department, Director of Research, or Director of Graduate/ Undergraduate Studies.)	
On the basis of the information available to me, I confirm that: ● I am aware of the research proposed and have read this application; ● To the best of my knowledge, the proposed design and scientific methodology do not raise ethical concerns; ● I support this research in principle, subject to ethical and other necessary reviews. ●	
Signature	
Name	
Role	
Date	

Appendix B. Study Poster

The Effects of Executive Functioning Skills on Academic Achievement
Ethics Approval Reference: CIA-22HT-028

VOLUNTEERS NEEDED FOR ONLINE STUDY OF ATTENTION AND MATHEMATICAL PERFORMANCE



This remotely-conducted study aims to explore the relationship between basic math skills and performance on games of memory and attention in young learners.

We are looking for volunteers, aged 7-8 years, to participate in this virtual study by meeting with Researcher Julia Burdulis via video conference to complete some child-friendly, age-appropriate computerized tasks relating to memory and attention abilities, and basic math skills. Eligible participants must be fluent English speakers and enrolled in Grade 1, 2, or 3 at any elementary school. You are invited to participate in this online study for 1 session. The session would take about 30 minutes of yours' and your child's time.

If you are interested and would like more information please contact Researcher Julia Burdulis at julia.burdulis@education.ox.ac.uk. There is no obligation to take part.

Appendix C. Study Information Sheet

Department of Education
[Redacted]
julia.burdulis@education.ox.ac.uk
MSc Education Student

The Relationship between Executive Functioning and Mathematical Performance

PARTICIPANT INFORMATION SHEET

Central University Research Ethics Committee Approval Reference: CIA-22HT-028

Your child is being invited to take part in a research project. Before you decide if you are comfortable with your child taking part, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Please contact me via email regarding anything that is not clear or if you would like more information. Take time to decide whether you wish to take part.

Why is this research being conducted?

This research is being conducted to advance the field of educational research by investigating young learners' skills in math fluency, and how they relate to their ability to use their developing memory and attention skills. The aim of this study is to replicate previous research which has found a relationship between children's academic performance and their attention and memory abilities, suggesting that such skills may serve to enhance student learning.

Why have I been invited to take part?

Your child has been identified as a potential participant because they match the predetermined inclusion criteria:

- Aged 7-8 years old
- Enrolled in school
- Fluent in English
- Normal/corrected to normal vision
- No hearing impairments
- Able to recognize and name numbers 1-10

Do I have to take part?

No. It is up to you to decide whether or not to take part. You can withdraw your child from the study, without giving a reason, by advising me of this decision. You may request that your child's scores be

withdrawn from the dataset up until the research project is completed. Should this request be made, all your child's data will be destroyed and not included in analysis.

What will happen to my child if I decide to have them take part in the research?

- Parents/guardians interested in volunteering their child for participation are invited to complete the form sent by the researcher where they may consent to their child's participation and can select an appointment date and time when their child and a parent or guardian will meet the researcher virtually via video conference.
- During the video call, the study will be explained in a way that your child may understand, and you and your child will have the opportunity to ask any questions about the project before your child is asked whether they want to take part. If they do wish to participate and understand the project sufficiently, data collection will begin.
- Each participating child will then complete 3 tasks over the course of a 30-minute session. The tasks have been tailored specifically for young children and are both short and light-hearted. They include:
    - A simple recall task where children remember pictures or patterns that they have been shown
    - A brief attention skills game
    - A basic number skills task
- Your child can ask to pause or stop the research activities at any time
- Children will be able to take a short break during the session. Every effort will be made to ensure that the research sessions are enjoyable and relaxed for the children.

What are the possible benefits and disadvantages and risks in taking part?

While there are no immediate benefits for those people participating in the project, it is hoped that this research will lead to a better understanding of the profile of young learners' attentional abilities, and how they relate to academic achievement in mathematics.

There is no risk in your child taking part in the study. Administration of the tasks is brief, and your child will have the option of taking a break to keep their mind fresh for both tasks involved in the study.

What information will be collected and why is the collection of this information relevant for achieving the research objectives?

Data to be collected from participants includes age, gender, and test scores from the attention and memory tasks and arithmetic test. Your child's date of birth will be collected for the purpose of

calculating their age in months at the time of testing, however DOB will not be included in the dataset and will then be destroyed.

This data will be stored in Nexus 365 OneDrive for Business, which has been approved by the University's Information Security team for the storage of research data. Per University Policy, this anonymized data will be stored for 3 years following publication.

Parents/guardians' names and email addresses and their child's name will be collected for the purpose of communicating about study information. Once data collection has been completed, these details will be destroyed.

The project supervisor will have access to the research data, however the supervisor will only have access to the anonymized dataset.

Will the research be published? Could I be identified from any publications or other research outputs?

The findings from the research will be written up in a n MSc dissertation. Children will not be identifiable from any data outputs.

A copy of the MSc dissertation will be deposited both in print and online in the Oxford University Research Archive where it will be publicly available to facilitate its use in future research.

Data Protection

The University of Oxford is the data controller with respect to yours and your child's personal data, and as such will determine how your personal data is used in the study. The University will process your personal data for the purpose of the research outlined above. Research is a task that is performed in the public interest. Further information about your rights with respect to your personal data is available at https://compliance.admin.ox.ac.uk/individual-rights.

Who has reviewed this study?

This study has received ethics approval from a subcommittee of the University of Oxford Central University Research Ethics Committee. (Ethics reference: **CIA-22HT-028)**.

Who do I contact if I have a concern about the research or I wish to complain?

If you have a concern about any aspect of this study, please contact me, Julia Burdulis, at julia.burdulis@education.ox.ac.uk and I in the first instance and I will do our best to answer your query and If you still have concerns that you feel I will acknowledge your concern within 10 working days and give you an indication of how it will be dealt with. If you remain unhappy or wish to make a formal

complaint, please contact the Chair of the Research Ethics Committee at the University of Oxford who will seek to resolve the matter as soon as possible:

The Chair, Social Sciences & Humanities Interdivisional Research Ethics Committee;
Email: ethics@socsci.ox.ac.uk; Address: Research Services, University of Oxford, Boundary Brook House, Churchill Drive, Headington, Oxford OX3 7GB

Further Information and Contact Details

If you would like to discuss the research with someone beforehand (or if you have questions afterwards), please contact:

Julia Burdulis
Department of Education
15 Norham Gardens, Oxford, OX2 6PS
University email: julia.burdulis@education.ox.ac.uk

Appendix D. Parent Survey

Attention and Math Performance Study

Start of Block: Default Question Block

Q12

Thank you for your interest in enrolling your child in a study run by Oxford University looking at 7- 8 year old children's math and attention abilities. This form should take no more than 3 minutes and will allow you to set up a time for your child to complete the study.

Q1 Have you read the study information sheet?

- Yes (1)
- No (2)

Q2 Do you have any additional questions about the study? If yes, please type them below, and you wil receive a response in 2 days or less.

_____

End of Block: Default Question Block

Start of Block: Block 1

Q16

By giving consent below, you are agreeing to your child's participation in a study run by Oxford University looking at how children's math and attention abilities relate. If your child takes part, a researcher would meet with them via Zoom to do some activities with them. If you are happy for your child to take part, please select 'yes' below.

Q3 Do you consent to your child's participation in this study?

- Yes (1)
- No (2)

Q15 By selecting 'yes' above, you indicate that you have read and understood the details of the above study, and have had the opportunity to ask questions and discuss the study with others. You have received satisfactory answers to your questions. You understand that the project has received ethics clearance through the University of Oxford’s ethical approval process for research involving human participants, and understand who will have access to the data, how it will be stored and what will happen to the data at the end of the study. You understand that participation is voluntary and that you and your child are free to withdraw at any time, without giving any reason and without your child’s education being affected in any way. You understand how to raise a concern or make a complaint.

End of Block: Block 1

Start of Block: Block 3

Display This Question:

If Do you consent to your child's participation in this study? = Yes

Q8

Thank you for consenting to your child's participation in the study!

Display This Question:

If Do you consent to your child's participation in this study? = Yes

Q9 Please complete the following demographic questions about your child.

Display This Question:

If Do you consent to your child's participation in this study? = Yes

Q10 Child's first name:

_____

Display This Question:

If Do you consent to your child's participation in this study? = Yes

Q14 Child's date of birth

	Month	Day	Year

Date of Birth (1)	▼ 01 (1 ... 12 (12)	▼ 01 (1 ... 31 (31)	▼ 2013 (1 ... 2015 (3)

Display This Question:

If Do you consent to your child's participation in this study? = Yes

Q15 Child's gender

- Male (1)
- Female (2)
- Other (please indicate below) (3)

_____

Display This Question:

If Do you consent to your child's participation in this study? = Yes

Q17 Email to send Zoom link:

_____

End of Block: Block 3

Start of Block: Block 2

Display This Question:

If Do you consent to your child's participation in this study? = Yes

Q8 Please select a time for your child to complete the study with the primary investigator via Zoom call.

Display This Choice:

If Quota 88 Has Not Been Met

- June 24 2- 2:30 pm EST (88)

Display This Choice:

If Quota 89 Has Not Been Met

- June 24 2:30- 3 pm EST (89)

Display This Choice:

If Quota 90 Has Not Been Met

- June 24 3- 3:30 pm EST (90)

Display This Choice:

If Quota 91 Has Not Been Met

- June 24 3:30- 4 pm EST (91)

Display This Choice:

If Quota 92 Has Not Been Met

- June 24 4- 4:30 pm EST (92)

Display This Choice:

If Quota 93 Has Not Been Met

- June 24 4:30- 5 pm EST (93)

Display This Choice:

If Quota 84 Has Not Been Met

- June 26 3- 3:30 pm EST (84)

Display This Choice:

If Quota 85 Has Not Been Met

○ June 26 3:30- 4 pm EST (85)

Display This Choice:

If Quota 86 Has Not Been Met

○ June 26 4- 4:30 pm EST (86)

Display This Choice:

If Quota 87 Has Not Been Met

○ June 26 4:30- 5 pm EST (87)

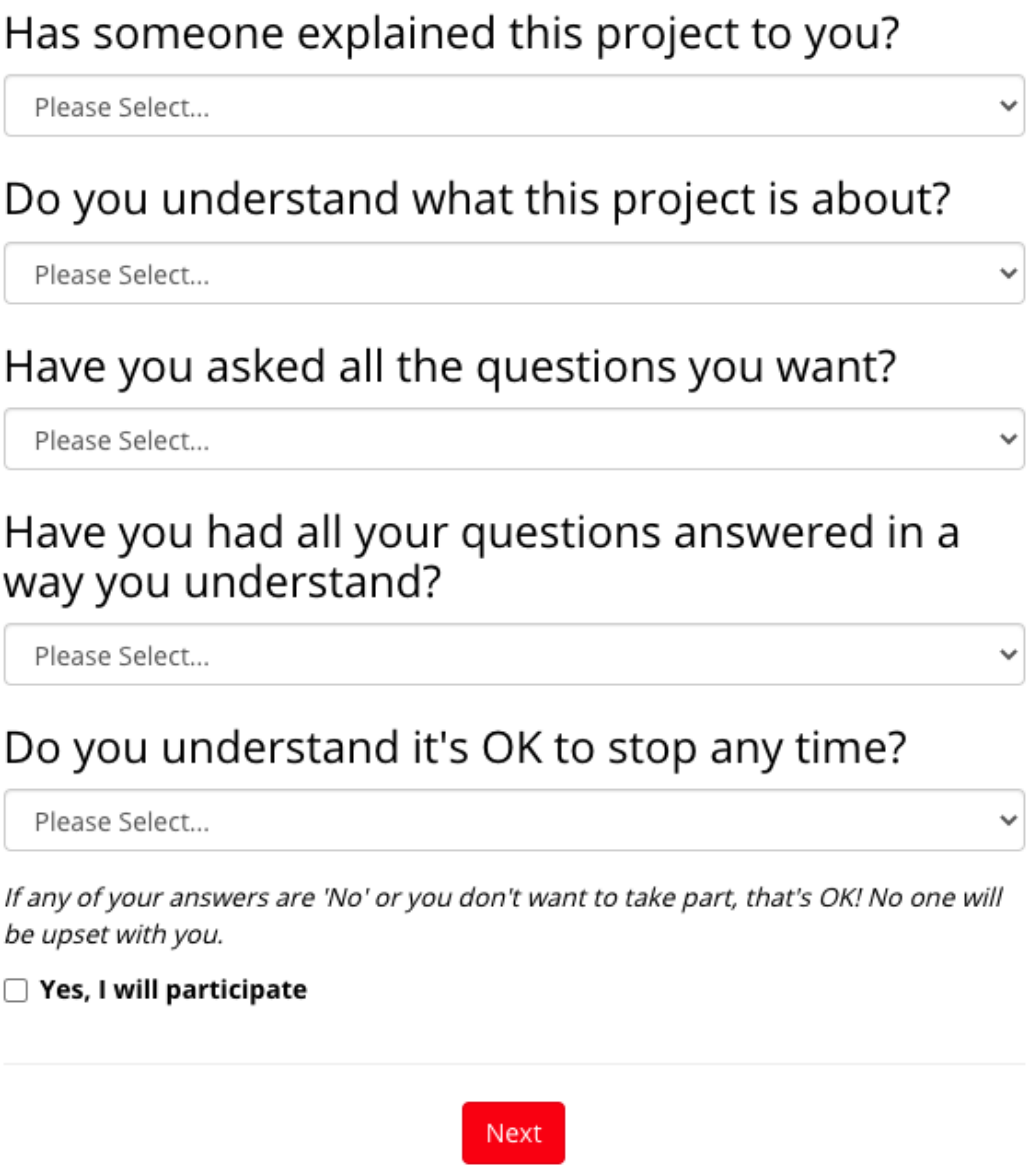
Display This Choice:

If Quota 123 Has Been Met

○ None of these times work, please contact me to arrange a different time (123)

End of Block: Block 2

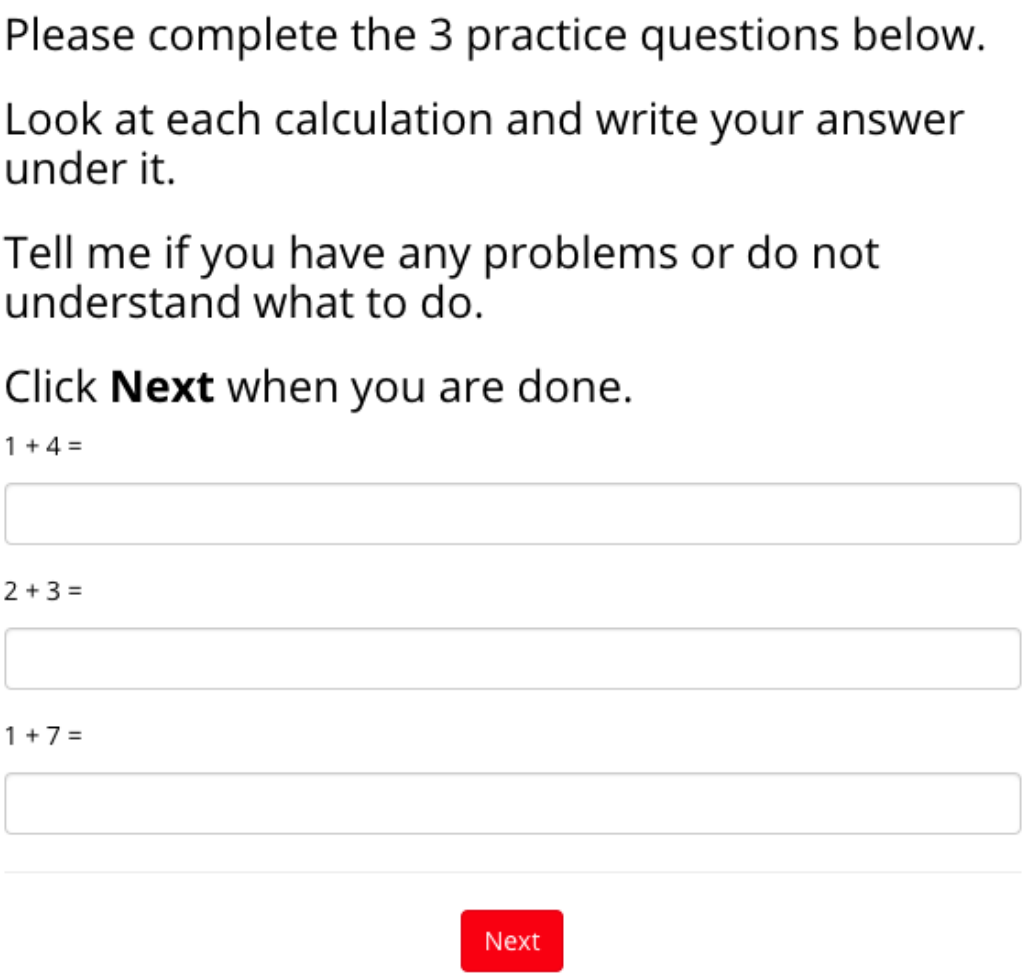
Appendix E. Child Assent Form in Gorilla

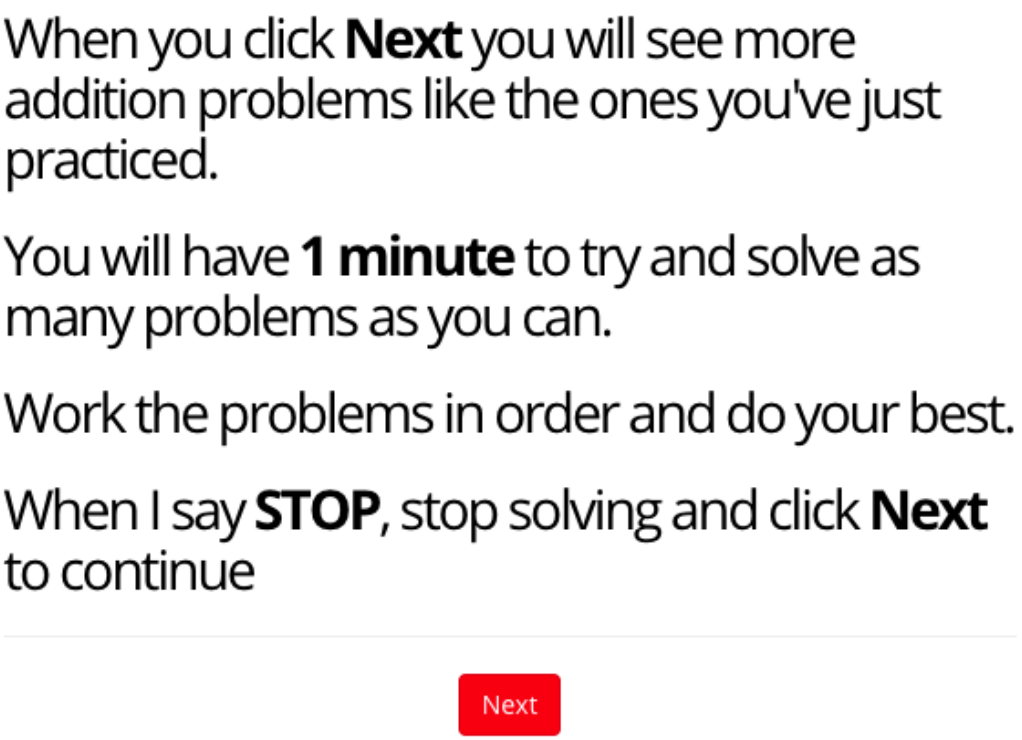


Appendix F. Screenshots of TOBANS Arithmetic Subtests in Gorilla

Note: Screenshots of math problems are not to scale.

Addition




When you click **Next** you will see more addition problems like the ones you've just practiced.
You will have **1 minute** to try and solve as many problems as you can.
Work the problems in order and do your best.
When I say **STOP**, stop solving and click **Next** to continue
Next

2 + 1 =

1 + 4 =

1 + 2 =

4 + 1 =

3 + 5 =

2 + 3 =

1 + 3 =

4 + 2 =

3 + 1 =

2 + 7 =

4 + 3 =

1 + 5 =

6 + 2 =

2 + 8 =

3 + 6 =

5 + 4 =

2 + 5 =

5 + 2 =

7 + 2 =

4 + 5 =

1 + 7 =

3 + 3 =

4 + 4 =

2 + 6 =

8 + 1 =

5 + 5 =

6 + 3 =

2 + 2 =

5 + 3 =

8 + 2 =

5 + 4 =

2 + 5 =

5 + 2 =

7 + 2 =

4 + 5 =

1 + 7 =

3 + 3 =

4 + 4 =

2 + 1 =

1 + 4 =

1 + 2 =

4 + 1 =

3 + 5 =

2 + 3 =

1 + 3 =

4 + 2 =

3 + 1 =

2 + 7 =

4 + 3 =

1 + 5 =

6 + 2 =

2 + 8 =

3 + 6 =

2 + 6 =

8 + 1 =

5 + 5 =

6 + 3 =

2 + 2 =

5 + 3 =

8 + 2 =

4 + 2 =

3 + 1 =

2 + 7 =

4 + 3 =

1 + 5 =

6 + 2 =

2 + 8 =

3 + 6 =

4 + 2 =

3 + 1 =

2 + 7 =

4 + 3 =

1 + 5 =

1 + 3 =

6 + 2 =

4 + 2 =

8 + 1 =

2 + 5 =

2 + 1 =

5 + 2 =

1 + 4 =

7 + 2 =

1 + 2 =

4 + 5 =

4 + 1 =

1 + 7 =

3 + 5 =

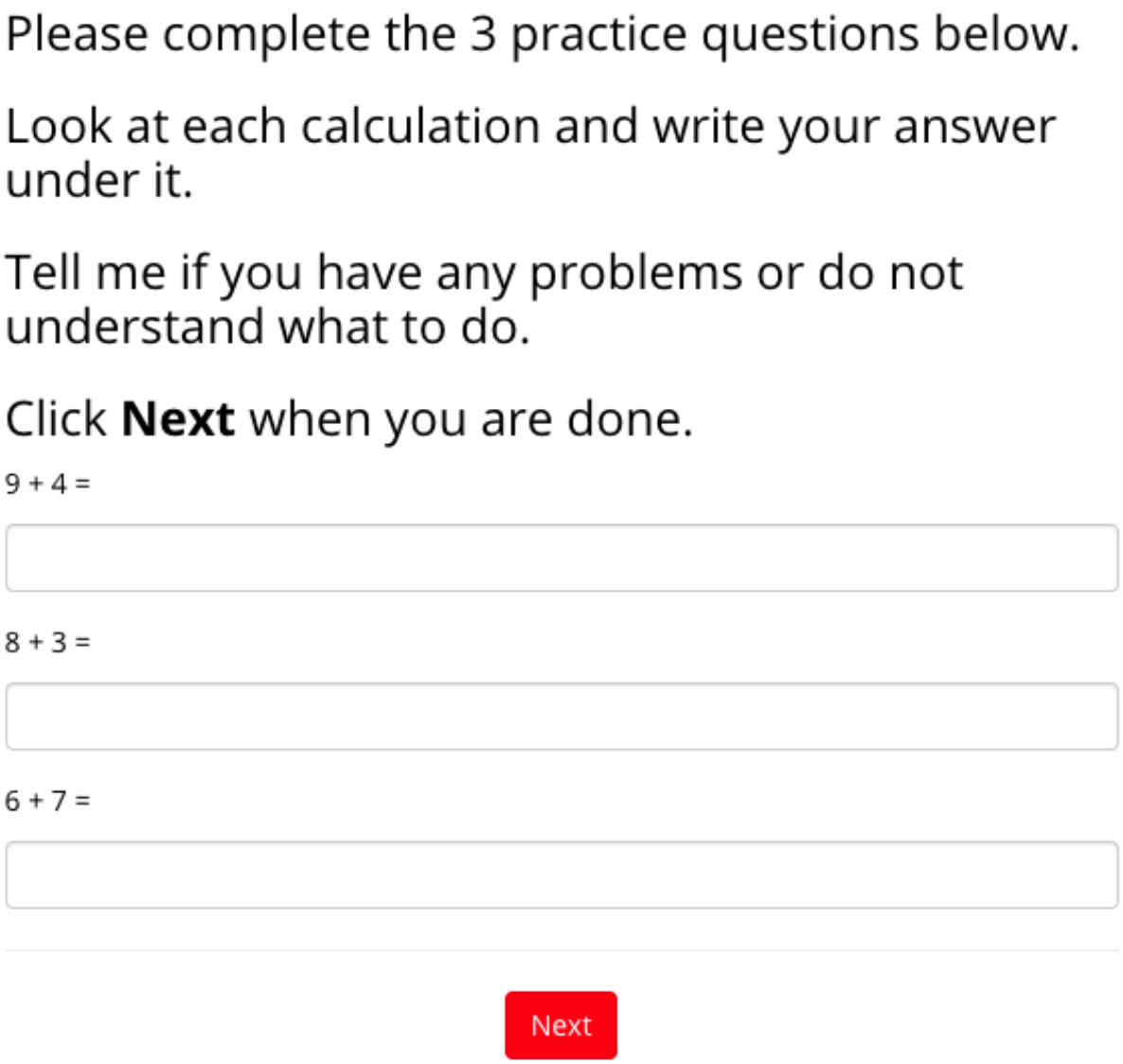
3 + 3 =

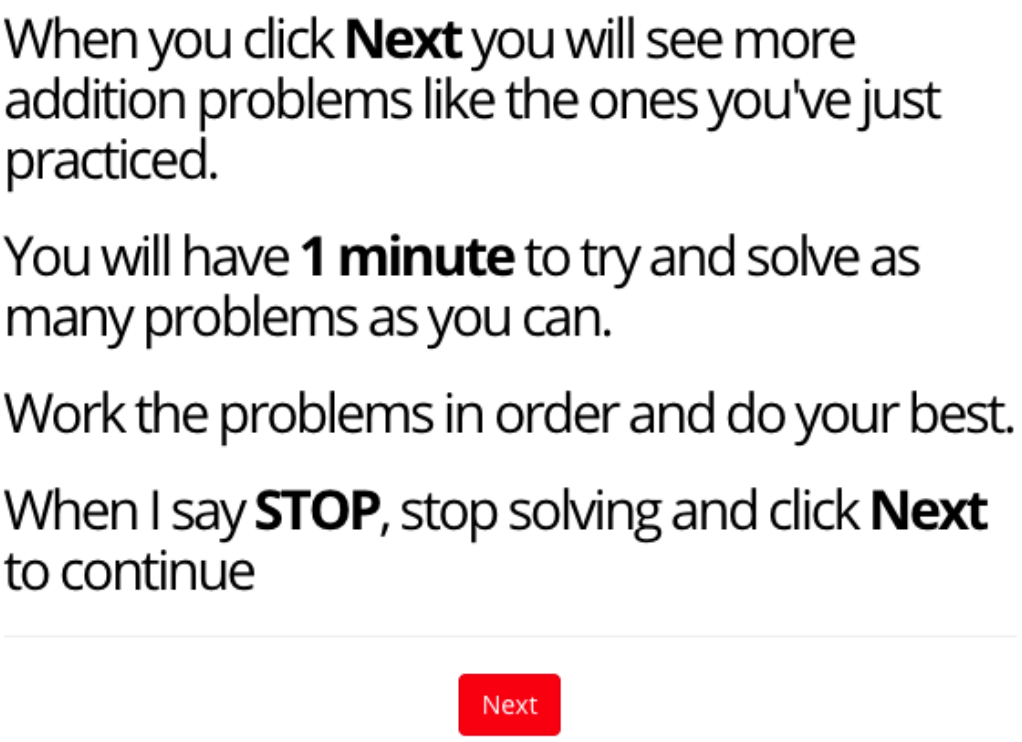
2 + 3 =

4 + 4 =

Next

Addition with carry




When you click **Next** you will see more addition problems like the ones you've just practiced.
You will have **1 minute** to try and solve as many problems as you can.
Work the problems in order and do your best.
When I say **STOP**, stop solving and click **Next** to continue
Next

9 + 2 =

8 + 4 =

5 + 7 =

7 + 4 =

6 + 5 =

9 + 7 =

5 + 9 =

6 + 8 =

6 + 6 =

7 + 6 =

8 + 5 =

8 + 7 =

6 + 9 =

3 + 9 =

6 + 7 =

9 + 9 =

7 + 9 =

9 + 3 =

5 + 8 =

7 + 8 =

6 + 5 =

7 + 7 =

8 + 9 =

4 + 6 =

3 + 8 =

2 + 9 =

9 + 8 =

6 + 7 =

8 + 4 =

9 + 7 =

6 + 9 =

3 + 8 =

7 + 6 =

9 + 4 =

5 + 8 =

9 + 9 =

8 + 4 =	5 + 7 =
6 + 9 =	6 + 9 =
7 + 7 =	9 + 3 =
5 + 9 =	6 + 5 =
6 + 5 =	7 + 8 =
2 + 9 =	6 + 6 =
8 + 5 =	8 + 4 =
7 + 8 =	7 + 6 =
9 + 3 =	5 + 9 =

9 + 9 =

6 + 8 =

4 + 9 =

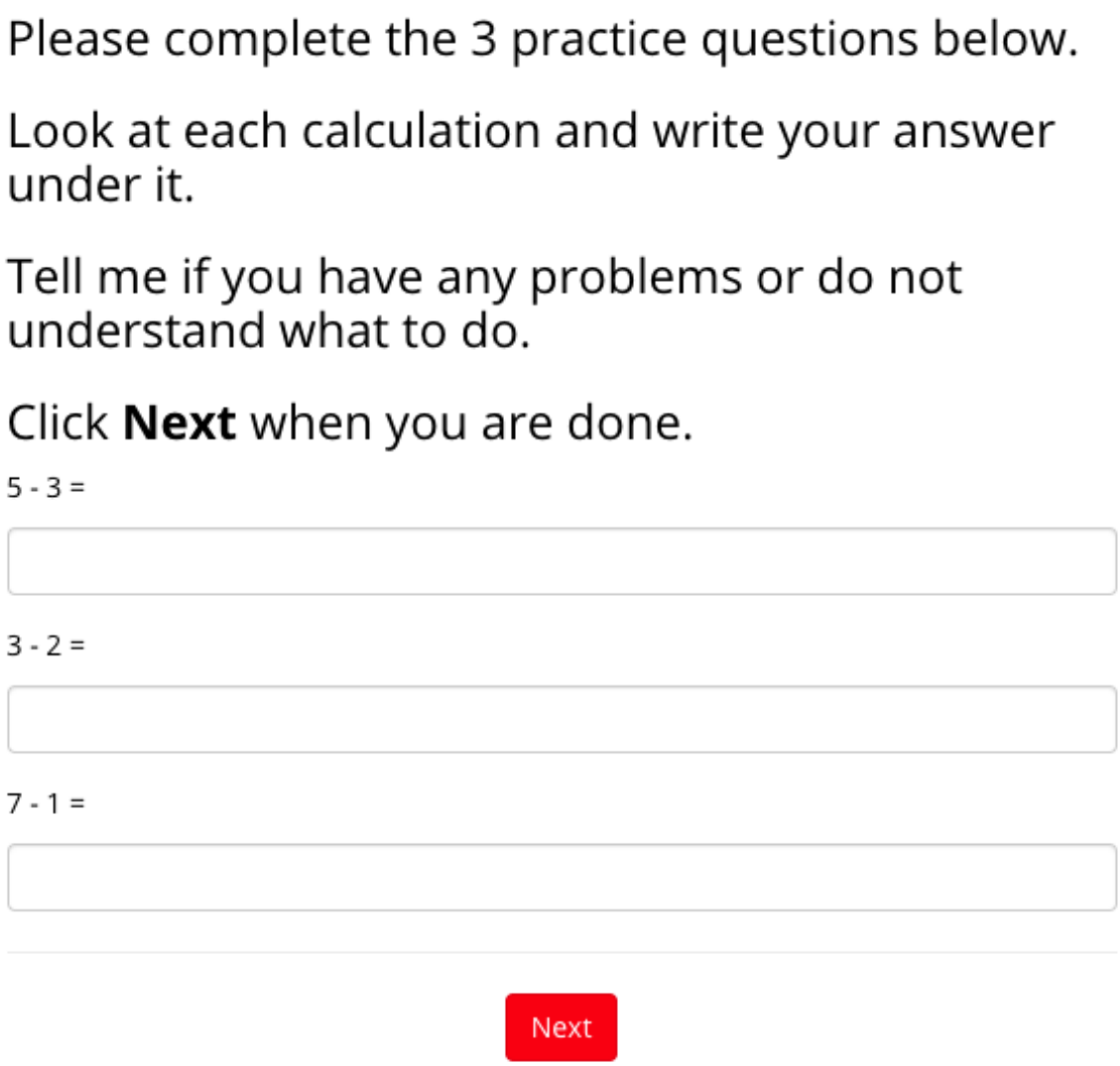
6 + 7 =

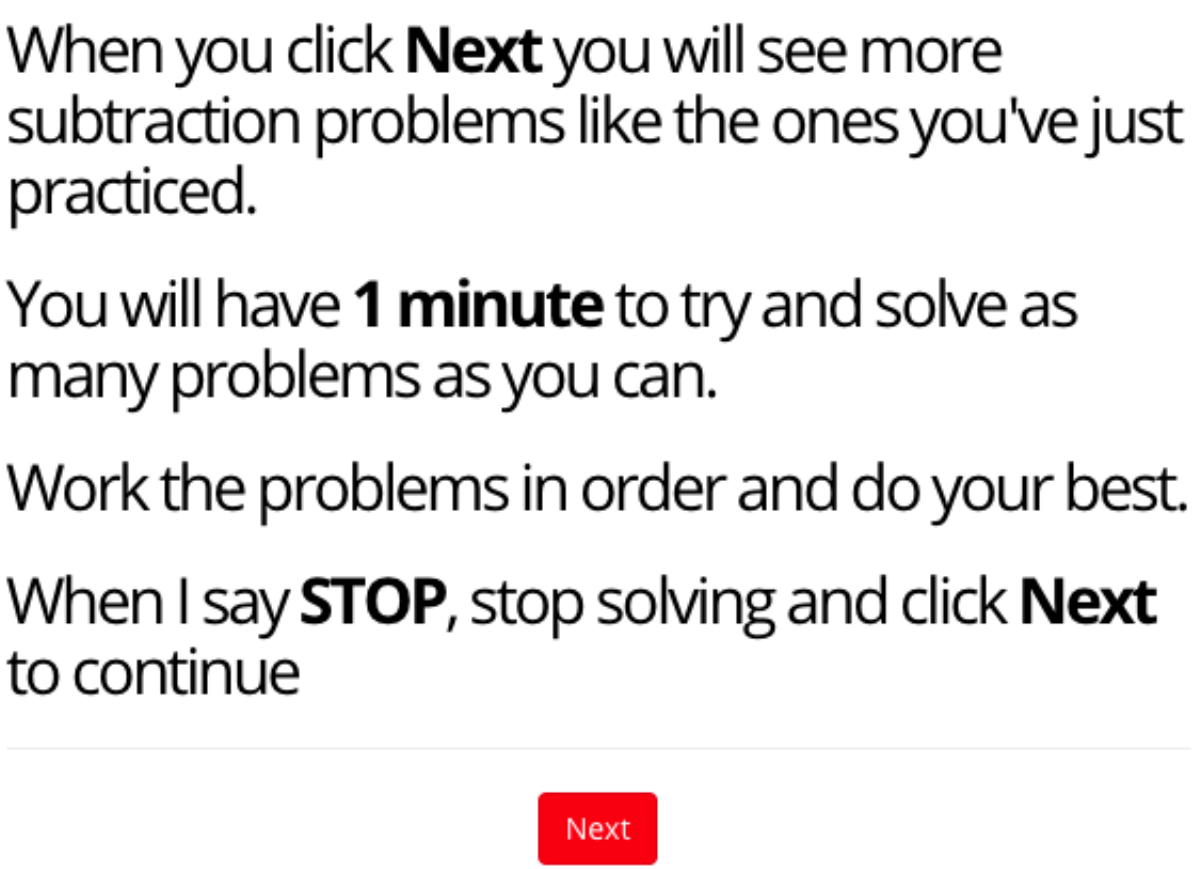
5 + 6 =

9 + 2 =

Next

Subtraction




When you click **Next** you will see more subtraction problems like the ones you've just practiced.
You will have **1 minute** to try and solve as many problems as you can.
Work the problems in order and do your best.
When I say **STOP**, stop solving and click **Next** to continue
Next

2 - 1 =

4 - 1 =

4 - 2 =

7 - 3 =

6 - 1 =

5 - 2 =

6 - 4 =

3 - 1 =

6 - 5 =

7 - 4 =

9 - 2 =

7 - 2 =

6 - 3 =

9 - 6 =

6 - 5 =

9 - 4 =

5 - 3 =

8 - 6 =

5 - 1 =

9 - 8 =

3 - 2 =

7 - 5 =

8 - 3 =

7 - 1 =

9 - 3 =

8 - 5 =

9 - 5 =

5 - 4 =

6 - 2 =

9 - 3 =

8 - 5 =

9 - 5 =

5 - 4 =

6 - 2 =

9 - 3 =

9 - 2 =

7 - 2 =

6 - 3 =

3 - 1 =

6 - 5 =

7 - 4 =

3 - 2 =

7 - 5 =

8 - 3 =

7 - 1 =

9 - 6 =

6 - 5 =

9 - 4 =

5 - 3 =

8 - 6 =

9 - 3 =

6 - 5 =

9 - 4 =

5 - 3 =

8 - 6 =

5 - 1 =

9 - 8 =

7 - 3 =

6 - 5 =

7 - 4 =

5 - 1 =

9 - 8 =

2 - 1 =

4 - 1 =

4 - 2 =

7 - 3 =

6 - 1 =

5 - 2 =

6 - 4 =

3 - 1 =

3 - 2 =

7 - 5 =

8 - 3 =

7 - 1 =

9 - 3 =

2 - 1 =

4 - 1 =

4 - 2 =

7 - 3 =

6 - 1 =

5 - 2 =

6 - 4 =

3 - 1 =

9 - 5 =

5 - 4 =

6 - 2 =

9 - 3 =

9 - 2 =

7 - 2 =

6 - 3 =

Next

Subtraction with carry

Please complete the 3 practice questions below.

Look at each calculation and write your answer under it.

Tell me if you have any problems or do not understand what to do.

Click **Next** when you are done.

12 - 3 =

13 - 8 =

17 - 9 =

Next

When you click **Next** you will see more subtraction with carry problems like the ones you've just practiced.

You will have **1 minute** to try and solve as many problems as you can.

Work the problems in order and do your best.

When I say **STOP**, stop solving and click **Next** to continue

Next

14 - 5 =

18 - 9 =

15 - 9 =

11 - 4 =

11 - 2 =

11 - 8 =

13 - 5 =

12 - 7 =

11 - 6 =

12 - 9 =

15 - 6 =

14 - 8 =

16 - 7 =

13 - 5 =

17 - 8 =

18 - 9 =

11 - 5 =

16 - 8 =

17 - 8 =

14 - 6 =

12 - 4 =

15 - 8 =

13 - 9 =

11 - 7 =

16 - 7 =

18 - 9 =

11 - 7 =

11 - 4 =

16 - 9 =

11 - 9 =

14 - 7 =

14 - 5 =

15 - 8 =

17 - 8 =

18 - 9 =

13 - 5 =

11 - 9 =

16 - 9 =

17 - 9 =

15 - 6 =

12 - 4 =

11 - 6 =

13 - 8 =

18 - 9 =

18 - 9 =

13 - 5 =

11 - 5 =

12 - 9 =

13 - 9 =

16 - 8 =

12 - 6 =

11 - 2 =

16 - 7 =

17 - 9 =

13 - 4 =

13 - 6 =

17 - 8 =

15 - 8 =

15 - 9 =

11 - 8 =

Next

Multiplication

Please complete the 3 practice questions below.

Look at each calculation and write your answer under it.

Tell me if you have any problems or do not understand what to do.

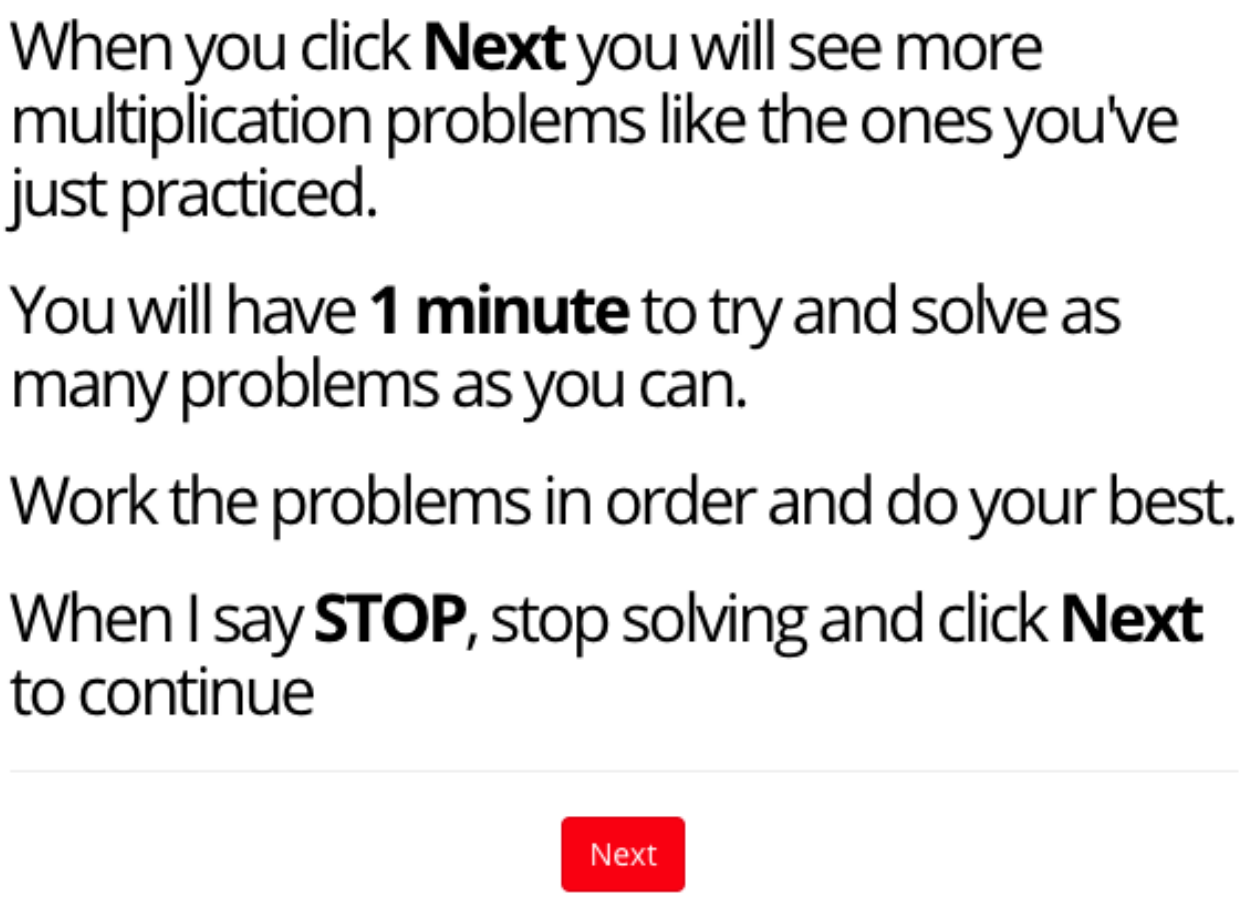
Click **Next** when you are done.

1 x 4 =

2 x 2 =

2 x 4 =

Next


When you click **Next** you will see more multiplication problems like the ones you've just practiced.
You will have **1 minute** to try and solve as many problems as you can.
Work the problems in order and do your best.
When I say **STOP**, stop solving and click **Next** to continue
Next

3 x 2 =	4 x 2 =
1 x 4 =	5 x 6 =
5 x 3 =	2 x 7 =
2 x 4 =	3 x 1 =
1 x 8 =	4 x 4 =
3 x 4 =	1 x 5 =
2 x 2 =	3 x 6 =
1 x 10 =	2 x 9 =
3 x 3 =	3 x 7 =
5 x 2 =	1 x 2 =
6 x 6 =	6 x 7 =
7 x 4 =	8 x 6 =
9 x 7 =	7 x 3 =
6 x 7 =	9 x 4 =
8 x 6 =	6 x 9 =
7 x 3 =	3 x 4 =
9 x 4 =	1 x 5 =
6 x 9 =	3 x 6 =
8 x 7 =	2 x 9 =
9 x 3 =	3 x 7 =

1 x 2 =

6 x 6 =

7 x 4 =

2 x 2 =

1 x 10 =

3 x 2 =

1 x 4 =

5 x 3 =

2 x 4 =

1 x 8 =

9 x 7 =

6 x 7 =

8 x 6 =

7 x 3 =

9 x 4 =

6 x 9 =

8 x 7 =

9 x 3 =

3 x 2 =

1 x 4 =

8 x 7 =

9 x 3 =

3 x 2 =

1 x 4 =

5 x 3 =

2 x 4 =

1 x 8 =

3 x 4 =

9 x 7 =

6 x 7 =

5 x 3 =

2 x 4 =

1 x 8 =

3 x 4 =

2 x 2 =

8 x 6 =

2 x 2 =

1 x 10 =

3 x 3 =

5 x 2 =

4 x 2 =

5 x 6 =

2 x 7 =

1 x 5 =

3 x 6 =

2 x 9 =

3 x 7 =

1 x 2 =

6 x 6 =

7 x 4 =

4 x 8 =

6 x 6 =

1 x 10 =

7 x 8 =

9 x 4 =

4 x 3 =

2 x 6 =

5 x 7 =

3 x 9 =

8 x 3 =

6 x 5 =

7 x 9 =

10 x 2 =

1 x 5 =

3 x 8 =

6 x 4 =

3 x 3 =

5 x 9 =

2 x 2 =

9 x 3 =

6 x 5 =

5 x 9 =

9 x 8 =

2 x 8 =

1 x 7 =

4 x 9 =

3 x 5 =

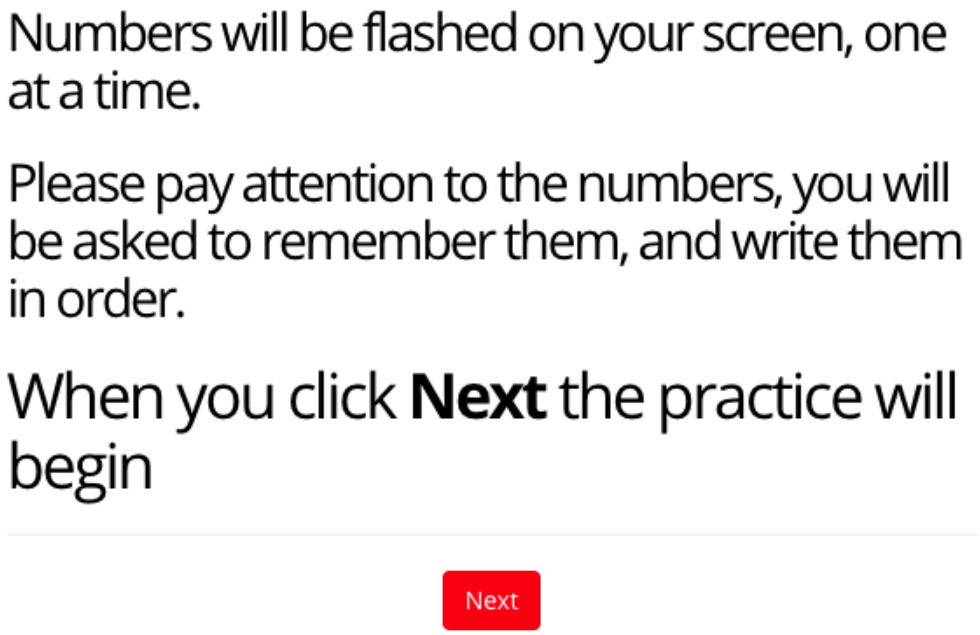
9 x 2 =

5 x 8 =

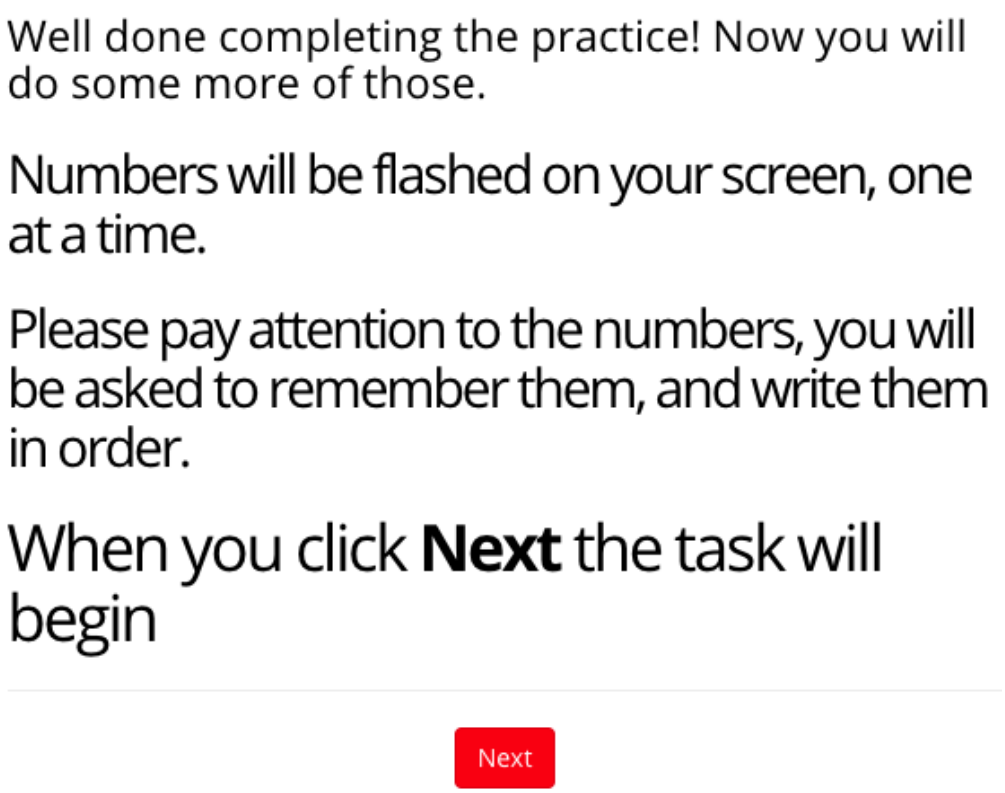
7 x 3 =

Appendix G. Screenshots of Digit Span Task

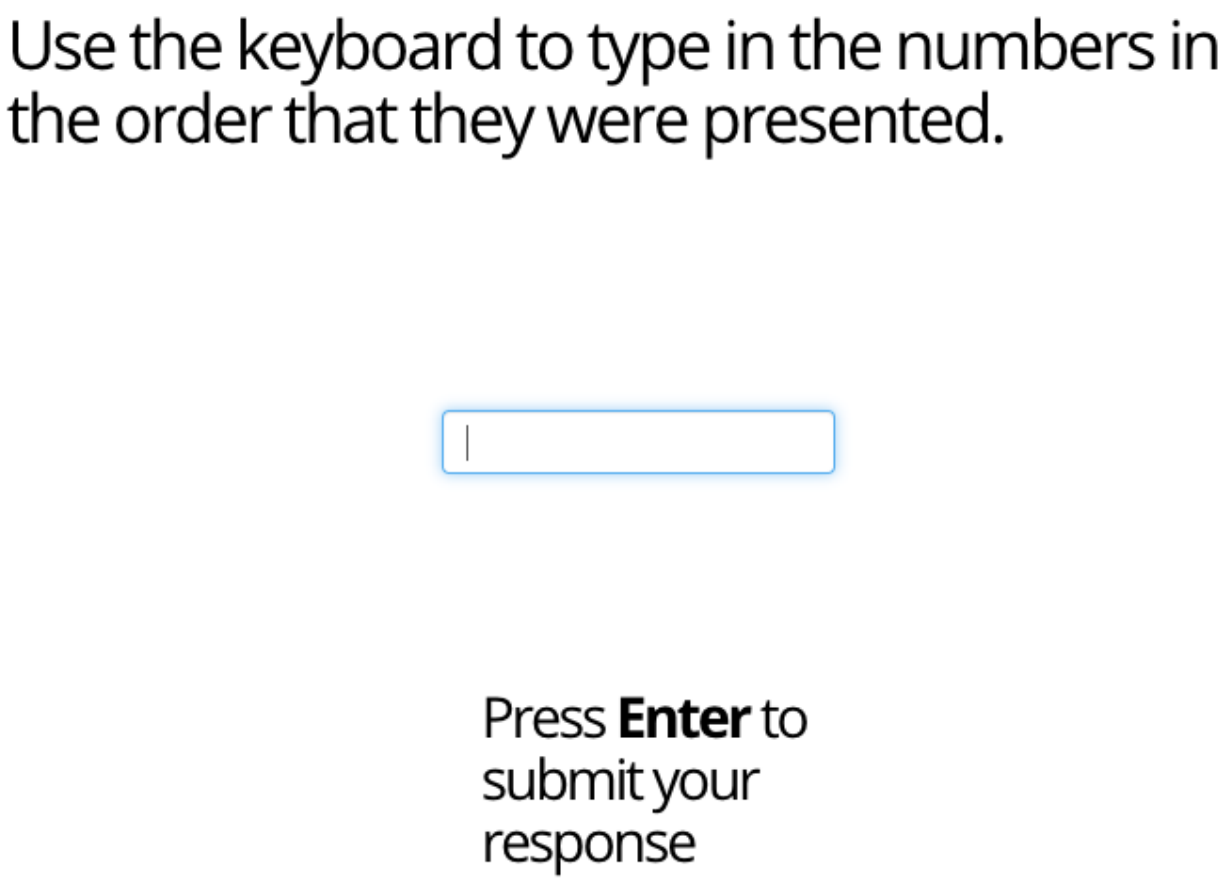
Practice Digit Span Instructions



Digit Span Task Instructions



Digit Span Response Entry


Use the keyboard to type in the numbers in the order that they were presented.
Press Enter to submit your response

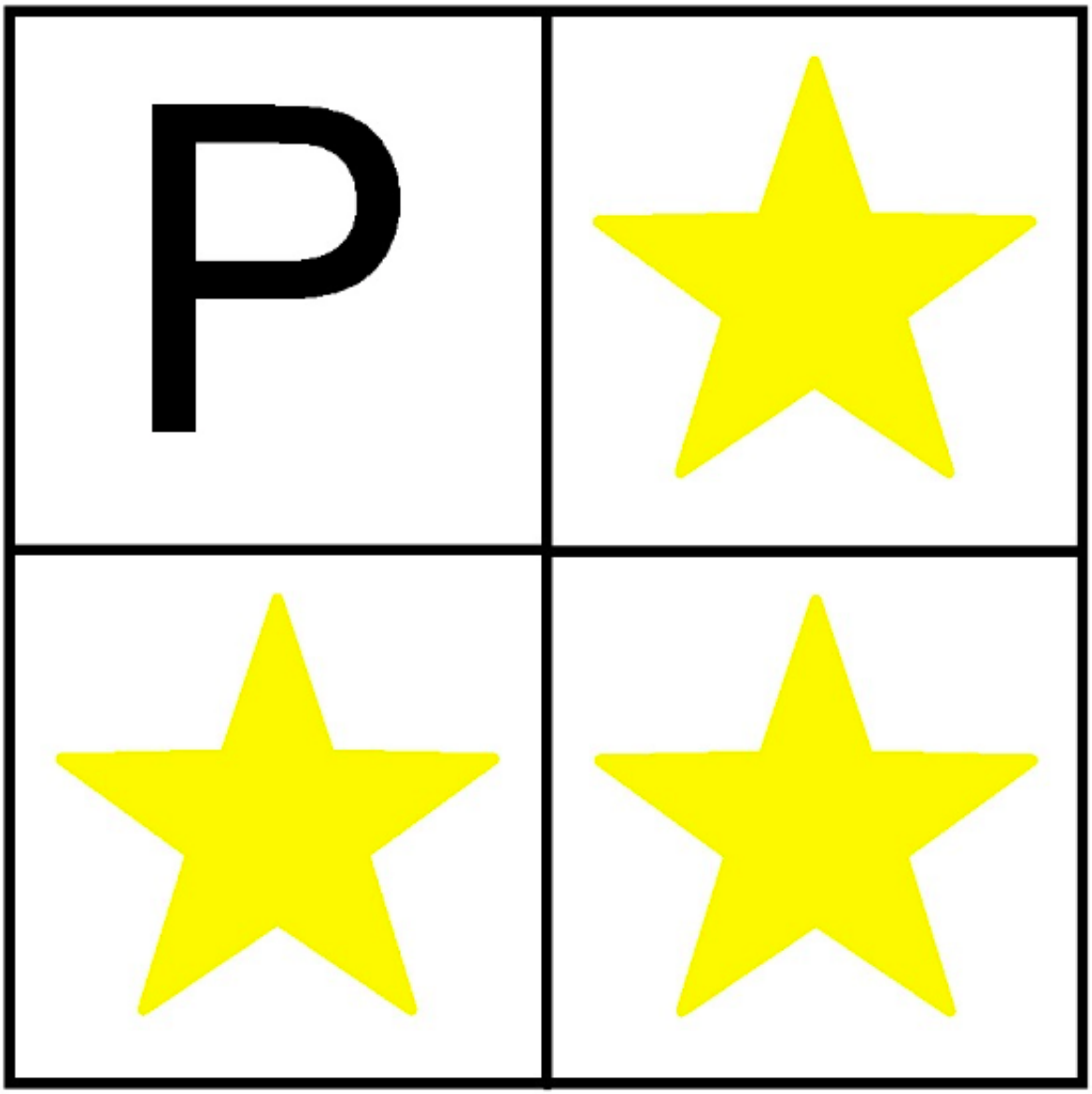
Appendix H. Screenshots of Go/No Go Task

Go/No Go Instructions, P target





P Stimulus Display



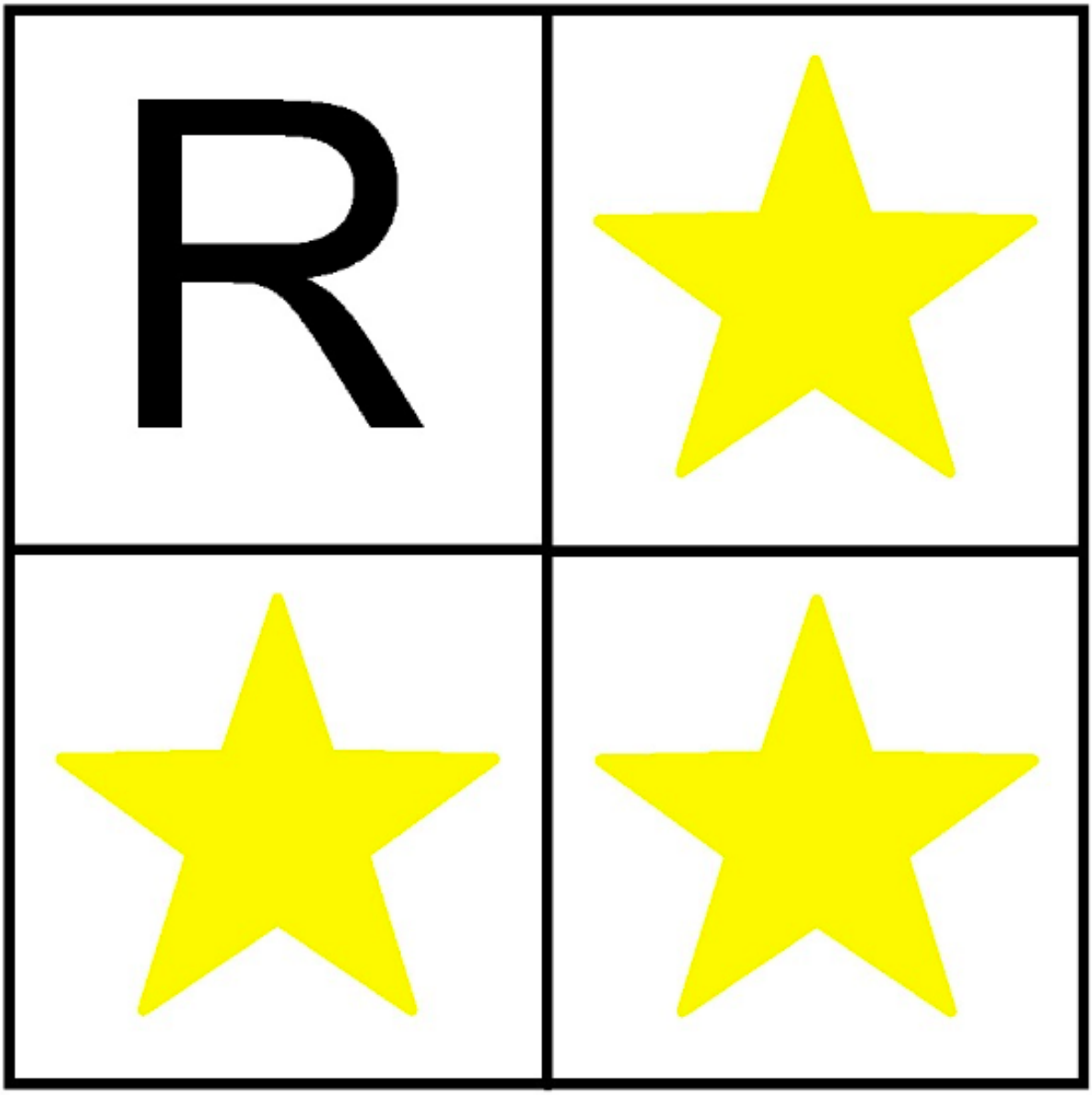
Go/No Go Instructions, R target






The figure originally presented here cannot be made freely available via ORA because of copyright.

R Stimulus Display



Appendix I. Data Collection Script

Hello *Child's Name*! My name is Julia, thank you for joining me today! Did a grown up tell you about this call today?

CHILD: Yes/No

(Y) That's great! Is it okay if I tell you some more about what we'll be doing today?
(N) That's okay. I'm going to tell you about what we're going to do today!

I am trying to learn how kids your age learn, by meeting online like this to do some really quick math tests and some memory activities. A grown up you know heard about my project, and decided to sign you up because you were the right age for it!
Do you have any questions for me about this project you're helping me out with?

answer any questions

So, the way this will work is first, I will help you to share your screen. That way I can see what you're doing, and help you if you have trouble getting to the math tests and activities.
Let's start with that, and then I'll tell you the next direction. Have you ever shared your screen on Zoom before?

CHILD: Yes/ No

I'll explain it, and then help you click the right buttons to do it too.

At the bottom of your screen, in the middle, click the green button with an arrow pointing up. It says "Share Screen" under it.

Child clicks share screen button

Now a new box just popped open, all you need to do is look at the bottom of that box for a blue button that say “Share, S-H-A-R-E” Do you see it? Go ahead and click that!

***Child clicks “share”**

Great job! Now I can see your screen. This is helpful so I can see what you’re doing in each activity.

Paste Gorilla Link into chat

Now can you move your mouse to the top of your screen? When you do that, you should be able to see the toolbar for zoom again.
To the left of the green button you clicked to share your screen with me, is a white button with a speech bubble that says “Chat”. It should have a red number “1” next to it. Can you click that please?
Great this is the chat, I just sent a link in it that you can click on, and it will open up a website. Go ahead and click on it!

Great job getting to the tests!

Assent

To get started, here are some questions for you to answer. I will read each one out loud to you, and then you can click on your answer, okay? If your answer is not “yes” to any of these, please tell me so I can help!

“Has someone explained this project to you?”

“Do you understand what this project is about?”

“Have you asked all the questions you want?”

“Have you had all your questions answered in a way you understand?”

“Do you understand it's OK to stop any time?”

Last, if you want to participate in this project, click the box at the bottom. It says “Yes, I will participate”

Child ticks box

I am so glad you want to help me out by doing these quick tests and activities. Remember that you are allowed to change your mind anytime you want, no one will be upset with you!

Go ahead and click the red button that says “Next”

Next

This page has some practice questions for your first math test, in addition. Before we begin the math tests, I’m going to turn my camera off, so it won’t be a distraction.

Turn camera off

But you can still hear my voice giving you directions.

Addition

I’ll read these instructions out loud for you, then you can do these practice problems.

“Please complete the 3 practice questions below. Look at each calculation and write your answer under it. Tell me if you have any problems or do not understand what to do. Click **Next** when you are done.”

So to start you need to click on the first box and type your answer, but then to go to the next one, you can always click “tab” and it goes to the next box so you don’t have to click it! Go ahead and do the practice now!

Completes practice

Click Next!

Next

Set up timer

Here are some more directions, I'll read them for you: "When you click Next you will see more addition problems like the ones you've just practiced. You will have **1 minute** to try and solve as many problems as you can. Work the problems in order and do your best. When I say **STOP**, stop solving and click **Next** to continue"

Okay so do you understand, when you click the red "next" the addition test will start, and I will time you for one minute. There are a lot of problems, so you won't have time to finish all of them. Just do your best to do as many as you can. If you're really stuck, it is ok to skip one. When I say stop you will skip the rest of the problems, scroll to the bottom of the page and click 'next'. Whenever you're ready, click "next" to start the addition test!

Next* *Child does test

time one minute

Stop! Scroll to the bottom of the page and click "Next"
*note which question child was on at 1 min

Next

Addition with Carry
Here are some more practice questions for the next test, addition with carry. This will work just like the last one. Do the practice questions, and hit next when you're done.

Child Completes Practice* *NEXT

reset timer

I'll read the instructions again: "When you click Next you will see more addition problems like the ones you've just practiced. You will have **1 minute** to try and solve as many problems as you can. Work the problems in order and do your best. When I say **STOP**, stop solving and click **Next** to continue"

Just like last time, you have 1 minute to solve as many problems as you can. Click Next when you're ready to begin the addition with carry test!

time one minute

Next* *Child does test

time one minute

Stop! Scroll to the bottom of the page and click "Next"

Next

Subtraction

Here are some more practice questions for the next test, subtraction. This will work just like the last one. Do the practice questions, and hit next when you're done.

Child Completes Practice* *NEXT

reset timer

Okay, just like last time, you have 1 minute to solve as many problems as you can. Click Next when you're ready to begin the subtraction test!

time one minute

Next* *Child does test

time one minute

Stop! Scroll to the bottom of the page and click "Next"

Next

Subtraction with Carry

Here are some more practice questions for the next test, subtraction with carry. This will work just like the last one. Do the practice questions, and hit next when you're done.

Child Completes Practice* *NEXT

reset timer

Okay, just like last time, you have 1 minute to solve as many problems as you can. Click Next when you're ready to begin the subtraction with carry test!

time one minute

Next* *Child does test

time one minute

Stop! Scroll to the bottom of the page and click "Next"

Next

Multiplication

Here are some more practice questions for the next test, multiplication. This will work just like the last one. Do the practice questions, and hit next when you're done.

Child Completes Practice* *NEXT

reset timer

Okay, just like last time, you have 1 minute to solve as many problems as you can. Click Next when you're ready to begin the multiplication test!

time one minute

Next* *Child does test

time one minute

Stop! Scroll to the bottom of the page and click "Next"

Next

Break

Great job! You have completed all the math tests. We have 2 activities left. We can take a 5 minute break, or you can click **Next** when you are ready to keep going !

Would you like to take a short break, or move on to the next activity?

Click 'next' when you're ready for the instructions for our next activity.

Next

Digit Span

Here are the instructions for the next task. I will read them out loud to you: “Numbers will be flashed on your screen, one at a time.Please pay attention to the numbers, you will be asked to remember them, and write them in order. When you click **Next** the practice will begin”

Do you understand? Pay attention to the numbers, they might move a little fast, and try to remember them. It will ask you to do your best to type them in order after. This one is just a practice, are you ready? Click “Next” to start.

__NEXT__

Do not prompt child to type numbers during task unless 10 seconds go by without them typing anything

Great job practicing! Go ahead and click next to see the instructions before you start the real thing

NEXT

I’ll read the instructions again: “Well done completing the practice! Now you will do some more of those. Numbers will be flashed on your screen, one at a time. Please pay attention to the numbers, you will be asked to remember them, and write them in order. When you click **Next** the task will begin”

Click “Next” when you’re ready to start!

Next

Do not prompt child to type numbers during task unless 10 seconds go by without them typing anything

Well done! Click Next

Next

Go/No Go

It's time to start the last activity! This is a task where you press the "space" button on your keyboard when you see a certain letter on your screen. The instructions will tell you which letter to look for! Let's read the directions and do some practice. Click 'Next'!

Next

I'll read the directions out loud with you: "Press Space if there is a P in the box"

Press Space!

Space

If there is an R in the box do not press anything.

Press Space to keep going with the directions now!

Space

Ok, now the next time you press space, the practice will start. Do you understand the directions? Press space when there is a P in the box, and do not press anything if you see an R in the box.

Press space when you're ready to start the practice.

Space* *does practice

Great job! Press 'space' to keep going!

Space

Great, let's practice again! Press space to see the directions again.

Space

Same thing, press space when you see P. Press Space!

Space

Do not press anything when you see R. Press space now to keep going with the directions!

Space

Press space to start practicing.

Space* *does practice

Great job! Press ‘space’ to keep going!

Space

Well done! Press ‘Space’ again

Space

Next up is the real thing. I’ll read the directions one more time to you: “Remember! Press Space if you see P. Don’t press anything if you see R!”

It will not tell you if you are right or wrong, so do you best to remember the instructions!

Press Space!

Space

Now when you’re ready, you can press space, and it will start!

Space* *Child does activity

Great job! Click next

Next

Now you'll do the same activity but with new instructions. Listen while we read the new instructions:

"Now press space if there is an R in the box" Press Space!

Space

"If there is a P in the box, do not press anything. Practice starts after you press space"

Do you understand? Go ahead and press space to practice once you're ready!

Space* Practice

Nice job, let's practice again! Press 'space'

Space

Same thing, press space when you see R. Press 'space'!

SPACE

do not press anything when you see P. Press space when you're ready to practice some more.

Space* *does practice

Great job! Press space

Space

Well done! Press space again

Space

Next up is the real thing.

Space

I'll read the directions one more time to you: "Remember! Press Space if you see R. Don't press anything if you see P!" Press 'Space'

__Space__

Ok, when you're ready to start, press space!

__Space__

Child completes activity

Turn camera back on

Great job! Now all that's left to do is click "Finish"... now click "Next" and you're done!

Child clicks Finish

Ok, now I'll tell you how to stop sharing your screen with me. Just look at the top of your screen, there is a green bar that says "You are screen sharing" and Next to it in red it says "Stop share". Just go ahead and click the red button to stop sharing your screen.

Child ends screen share

OK that is everything! Before we say goodbye do you have any questions for me about the activities we did today?

Answer any questions

Thank you so much for meeting me today! You did some awesome work, and you were super helpful for my project! Bye!

To parent: From here, you can expect to hear from me one more time in August with my finished dissertation in case you're curious to read it, but I don't need anything else from you otherwise! If you are willing and able to share my contact information with parents and guardians with kids your child's age, that would go a long way, I'm still recruiting participants for 3 more weeks and

would love to get the word out any way possible. You have my email should anything come up regarding questions about the study, and you do have the option to withdraw your child's data anytime until August without giving a reason. Thank you so much to both of you for taking the time today!

Appendix J: Descriptive Statistics SPSS Output

Descriptive Statistics

Descriptives

Descriptive Statistics

	N	Range	Minimum	Maximum	Mean		Std. Deviation	Variance	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
TOT MOS	28	22	85	107	93.89	1.235	6.534	42.692	.373	.441	-.639	.858
ADD RAW	28	28	2	30	13.96	1.313	6.947	48.258	.883	.441	.288	.858
ADD W C RAW	27	19	0	19	9.04	.969	5.034	25.345	.342	.448	-.671	.872
SUB RAW	28	25	3	28	12.57	1.176	6.221	38.698	.663	.441	.238	.858
SUB W C RAW	28	25	0	25	7.43	1.140	6.033	36.402	1.147	.441	1.356	.858
MULT RAW	28	17	0	17	6.21	1.082	5.724	32.767	.366	.441	-1.221	.858
LATENT VAR TOBANS	27	3.81840	-1.42360	2.39480	.0000000	.19245009	1.00000000	1.000	.785	.448	.048	.872
DIG SPAN	28	3	0	3	1.11	.149	.786	.618	.296	.441	-.175	.858
MAXIMUM DIG SPAN	28	6	0	6	3.68	.353	1.867	3.485	-1.222	.441	.513	.858
P GNG	28	16	24	40	36.14	.640	3.385	11.460	-1.748	.441	5.029	.858
R GNG	28	15	25	40	35.54	.717	3.796	14.406	-1.415	.441	1.854	.858
P COMMISSION ERRORS	28	13	0	13	.96	.503	2.659	7.073	3.858	.441	16.386	.858
P OMISSION ERRORS	28	7	0	7	2.86	.366	1.938	3.757	.348	.441	-.355	.858
R COMMISSION ERRORS	28	11	0	11	1.32	.564	2.982	8.893	2.822	.441	7.214	.858
R OMISSION ERRORS	28	8	0	8	3.11	.413	2.183	4.766	.658	.441	-.019	.858
Valid N (listwise)	27											

Note. TOTMOS= Participant age in months; ADD RAW= Addition subtest raw scores; ADD W C RAW= Addition with carry subtest raw scores; SUB RAW= Subtraction subtest raw scores; SUB W C RAW= Subtraction with carry subtest raw scores; MULT RAW= Multiplication subtest raw scores; LATENT VAR TOBANS= Latent Variable of TOBANS Arithmetic Subtests; DIGSPAN= Digit Span task total score; MAXIMUM DIG SPAN= Maximum digit span; P GNG= P target Go/No Go Task; R GNG= R target Go/No Go task; P_COM_ERR= Number of Commission errors made on P target Go/No Go Task; P_OM_ERR= Number of omission errors made on P target Go/No Go Task; R_COM_ERR= Number of commission errors made on R target Go/No Go Task; R_OM_ERR= Number of omission errors made on R target Go/No Go Task

Sample Statistics

Group Statistics

	GENDER	N	Mean	Std. Deviation	Std. Error Mean
TOT MOS	Male	18	95.00	6.334	1.493
	Female	10	91.90	6.740	2.132

Appendix K: TOBANS Subtest Factor Analysis SPSS Output

Descriptive Statistics

	Mean	Std. Deviation	Analysis N
ADD RAW	14.22	6.941	27
ADD W C RAW	9.04	5.034	27
SUB RAW	12.74	6.273	27
SUB W C RAW	7.56	6.110	27
MULT RAW	6.44	5.700	27

Correlation Matrix[a]

		ADD RAW	ADD W C RAW	SUB RAW	SUB W C RAW	MULT RAW
Correlation	ADD RAW	1.000	.757	.804	.722	.679
	ADD W C RAW	.757	1.000	.736	.740	.746
	SUB RAW	.804	.736	1.000	.835	.727
	SUB W C RAW	.722	.740	.835	1.000	.728
	MULT RAW	.679	.746	.727	.728	1.000
Sig. (1-tailed)	ADD RAW		<.001	<.001	<.001	<.001
	ADD W C RAW	.000		.000	.000	.000
	SUB RAW	.000	.000		.000	.000
	SUB W C RAW	.000	.000	.000		.000
	MULT RAW	.000	.000	.000	.000	

a. Determinant = .013

Note. ADD RAW= Addition subtest raw scores; ADD W C RAW= Addition with carry subtest raw scores; SUB RAW= Subtraction subtest raw scores; SUB W C RAW= Subtraction with carry subtest raw scores; MULT RAW= Multiplication subtest raw scores

Inverse of Correlation Matrix

	ADD RAW	ADD W C RAW	SUB RAW	SUB W C RAW	MULT RAW
ADD RAW	3.416	-1.147	-1.756	-.039	-.158
ADD W C RAW	-1.147	3.279	-.108	-.743	-1.048
SUB RAW	-1.756	-.108	4.736	-2.179	-.585
SUB W C RAW	-.039	-.743	-2.179	3.873	-.655
MULT RAW	-.158	-1.048	-.585	-.655	2.792

KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.875
Bartlett's Test of Sphericity	Approx. Chi-Square	102.117
	df	10
	Sig.	<.001

Note. ADD RAW= Addition subtest raw scores; ADD W C RAW= Addition with carry subtest raw scores; SUB RAW= Subtraction subtest raw scores; SUB W C RAW= Subtraction with carry subtest raw scores; MULT RAW= Multiplication subtest raw scores

Anti-image Matrices

		ADD RAW	ADD W C RAW	SUB RAW	SUB W C RAW	MULT RAW
Anti-image Covariance	ADD RAW	.293	-.102	-.109	-.003	-.017
	ADD W C RAW	-.102	.305	-.007	-.058	-.114
	SUB RAW	-.109	-.007	.211	-.119	-.044
	SUB W C RAW	-.003	-.058	-.119	.258	-.061
	MULT RAW	-.017	-.114	-.044	-.061	.358
Anti-image Correlation	ADD RAW	.876[a]	-.343	-.437	-.011	-.051
	ADD W C RAW	-.343	.887[a]	-.028	-.208	-.346
	SUB RAW	-.437	-.028	.835[a]	-.509	-.161
	SUB W C RAW	-.011	-.208	-.509	.870[a]	-.199
	MULT RAW	-.051	-.346	-.161	-.199	.917[a]

a. Measures of Sampling Adequacy(MSA)

Communalities

	Initial	Extraction
ADD RAW	1.000	.787
ADD W C RAW	1.000	.792
SUB RAW	1.000	.847
SUB W C RAW	1.000	.814
MULT RAW	1.000	.751

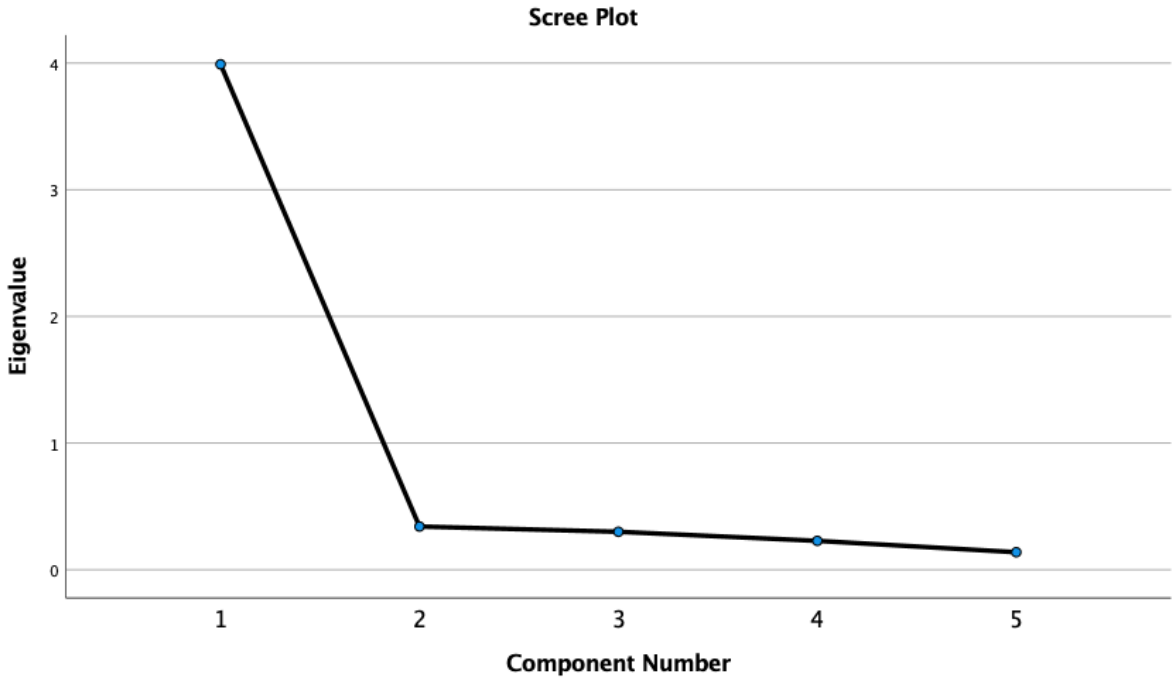
Extraction Method: Principal Component Analysis.

Note. ADD RAW= Addition subtest raw scores; ADD W C RAW= Addition with carry subtest raw scores; SUB RAW= Subtraction subtest raw scores; SUB W C RAW= Subtraction with carry subtest raw scores; MULT RAW= Multiplication subtest raw scores

Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.991	79.823	79.823	3.991	79.823	79.823
2	.342	6.831	86.654			
3	.300	6.003	92.657			
4	.228	4.569	97.225			
5	.139	2.775	100.000			

Extraction Method: Principal Component Analysis.


Scree Plot
Eigenvalue
4
3
2
1
0
1
2
3
4
5
Component Number

Component Matrix[a]

	Component 1
SUB RAW	.920
SUB W C RAW	.902
ADD W C RAW	.890
ADD RAW	.887
MULT RAW	.867

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Reproduced Correlations

		ADD RAW	ADD W C RAW	SUB RAW	SUB W C RAW	MULT RAW
Reproduced Correlation	ADD RAW	.787[a]	.790	.816	.800	.769
	ADD W C RAW	.790	.792[a]	.819	.803	.771
	SUB RAW	.816	.819	.847[a]	.830	.797
	SUB W C RAW	.800	.803	.830	.814[a]	.782
	MULT RAW	.769	.771	.797	.782	.751[a]
Residual[b]	ADD RAW		-.033	-.012	-.078	-.090
	ADD W C RAW	-.033		-.083	-.063	-.025
	SUB RAW	-.012	-.083		.005	-.070
	SUB W C RAW	-.078	-.063	.005		-.054
	MULT RAW	-.090	-.025	-.070	-.054	

Extraction Method: Principal Component Analysis.

a. Reproduced communalities

b. Residuals are computed between observed and reproduced correlations. There are 6 (60.0%) nonredundant residuals with absolute values greater than 0.05.

Note. ADD RAW= Addition subtest raw scores; ADD W C RAW= Addition with carry subtest raw scores; SUB RAW= Subtraction subtest raw scores; SUB W C RAW= Subtraction with carry subtest raw scores; MULT RAW= Multiplication subtest raw scores

Component Score Coefficient Matrix

	Component 1
ADD RAW	.222
ADD W C RAW	.223
SUB RAW	.231
SUB W C RAW	.226
MULT RAW	.217

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
Component Scores.

Component Score Covariance Matrix

Component	1
1	1.000

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.
Component Scores.

Appendix L: Correlation SPSS Output

Correlation Between TOBANS Performance and all Executive Functioning Measures and Age

Correlations

		Statistic				
Variable	Variable2	Correlation	Count	Lower C.I.	Upper C.I.	Notes
DIGSPAN	TOBANS_PERFORMANCE	.451	27	.085	.709	
MAX_SPAN	TOBANS_PERFORMANCE	.263	27	-.130	.585	
P_COMM_ERR	TOBANS_PERFORMANCE	-.249	27	-.575	.145	
P_OM_ERR	TOBANS_PERFORMANCE	-.029	27	-.404	.355	
PGNG	TOBANS_PERFORMANCE	.214	27	-.181	.549	
R_COMM_ERR	TOBANS_PERFORMANCE	-.290	27	-.604	.101	
R_OM_ERRORS	TOBANS_PERFORMANCE	.128	27	-.265	.485	
RGNG	TOBANS_PERFORMANCE	.139	27	-.254	.493	
TOTMOS	TOBANS_PERFORMANCE	.409	27	.035	.683	

Missing value handling: LISTWISE, EXCLUDE. C.I. Level: 95.0

Note. TOBANS_PERFORMANCE= Latent Variable of TOBANS Arithmetic Subtests; DIGSPAN= Digit Span task total score; MAX_SPAN= Maximum digit span; PGNG= P target Go/No Go Task; RGNG= R target Go/No Go task; P_OM_ERR= Number of omission errors made on P target Go/No Go Task; P_OM_ERR= Number of omission errors made on P target Go/No Go Task; P_COM_ERR= Number of Commission errors made on P target Go/No Go Task; R_OM_ERR= Number of omission errors made on R target Go/No Go Task; R_COM_ERR= Number of commission errors made on R target Go/No Go Task; TOTMOS= Participant age in months

Appendix M: Independent Samples T-Test SPSS Output

Despite not being normally distributed, the TOBANS latent variable was included in the independent samples t-test. This was so that SPSS would exclude the data from the participant with missing data on one of the TOBANS subtests. However, the group differences by TOBANS latent variable were reported in the results of the Mann-Whitney U test on account of being non-normally distributed and were therefore disregarded in the independent samples t-test.

Group Statistics

	GENDER	N	Mean	Std. Deviation	Std. Error Mean
TOT MOS	Male	18	95.00	6.334	1.493
	Female	9	91.44	6.984	2.328
MULT RAW	Male	18	7.06	6.073	1.431
	Female	9	5.22	4.969	1.656
DIG SPAN	Male	18	1.22	.878	.207
	Female	9	.89	.601	.200
P OMISSION ERRORS	Male	18	3.17	2.203	.519
	Female	9	2.22	1.302	.434
R OMISSION ERRORS	Male	18	3.56	2.502	.590
	Female	9	2.33	1.225	.408
LATENT VAR TOBANS	Male	18	.2046356	1.13547751	.26763461
	Female	9	-.4092712	.47702919	.15900973

Note. TOTMOS= Participant age in months; MULT RAW= Multiplication subtest raw scores; DIGSPAN= Digit Span task total score; P_OM_ERR= Number of omission errors made on P target Go/No Go Task; R_OM_ERR= Number of omission errors made on R target Go/No Go Task

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
TOT MOS	Equal variances assumed	.023	.880	1.330	25	.098	.196	3.556	2.674	-1.951	9.062
	Equal variances not assumed			1.286	14.758	.109	.218	3.556	2.766	-2.348	9.459
MULT RAW	Equal variances assumed	.509	.482	.782	25	.221	.442	1.833	2.344	-2.995	6.662
	Equal variances not assumed			.837	19.335	.206	.413	1.833	2.189	-2.743	6.410
DIG SPAN	Equal variances assumed	2.880	.102	1.021	25	.159	.317	.333	.327	-.339	1.006
	Equal variances not assumed			1.157	22.262	.130	.259	.333	.288	-.264	.930
P OMISSION ERRORS	Equal variances assumed	2.285	.143	1.180	25	.125	.249	.944	.800	-.704	2.593
	Equal variances not assumed			1.396	24.080	.088	.176	.944	.677	-.452	2.341
R OMISSION ERRORS	Equal variances assumed	3.108	.090	1.375	25	.091	.181	1.222	.889	-.608	3.052
	Equal variances not assumed			1.704	24.998	.050	.101	1.222	.717	-.255	2.700
LATENT VAR TOBANS	Equal variances assumed	5.940	.022	1.543	25	.068	.135	.61390681	.39781663	-.20541188	1.43322549
	Equal variances not assumed			1.972	24.605	.030	.060	.61390681	.31130753	-.02776536	1.25557898

Note. TOTMOS= Participant age in months; MULT RAW= Multiplication subtest raw scores; DIGSPAN= Digit Span task total score; P_OM_ERR= Number of omission errors made on P target Go/No Go Task; R_OM_ERR= Number of omission errors made on R target Go/No Go Task

Independent Samples Effect Sizes

		Standardizer[a]	Point Estimate	95% Confidence Interval	
				Lower	Upper
TOT MOS	Cohen's d	6.477	.479	-.310	1.258
	Hedges' correction	6.672	.465	-.301	1.221
	Glass's delta	6.740	.460	-.353	1.249
MULT RAW	Cohen's d	5.715	.412	-.373	1.189
	Hedges' correction	5.886	.400	-.362	1.155
	Glass's delta	4.968	.474	-.340	1.265
DIG SPAN	Cohen's d	.785	.411	-.374	1.188
	Hedges' correction	.808	.399	-.363	1.153
	Glass's delta	.568	.568	-.261	1.369
P OMISSION ERRORS	Cohen's d	1.928	.450	-.337	1.228
	Hedges' correction	1.985	.437	-.327	1.192
	Glass's delta	1.252	.692	-.159	1.511
R OMISSION ERRORS	Cohen's d	2.135	.588	-.207	1.372
	Hedges' correction	2.199	.571	-.201	1.332
	Glass's delta	1.160	1.083	.145	1.979

a. The denominator used in estimating the effect sizes.
Cohen's d uses the pooled standard deviation.
Hedges' correction uses the pooled standard deviation, plus a correction factor.
Glass's delta uses the sample standard deviation of the control group.

Note. TOTMOS= Participant age in months; MULT RAW= Multiplication subtest raw scores; DIGSPAN= Digit Span task total score; P_OM_ERR= Number of omission errors made on P target Go/No Go Task; R_OM_ERR= Number of omission errors made on R target Go/No Go Task; LATENT VAR TOBANS= Latent Variable of TOBANS Arithmetic Subtests

Appendix N: Mann-Whitney U Test SPSS Output

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.[a,b]	Decision
1	The distribution of LATENT VAR TOBANS is the same across categories of GENDER.	Independent-Samples Mann-Whitney U Test	.253[c]	Retain the null hypothesis.
2	The distribution of ADD RAW is the same across categories of GENDER.	Independent-Samples Mann-Whitney U Test	.089[c]	Retain the null hypothesis.
3	The distribution of ADD W C RAW is the same across categories of GENDER.	Independent-Samples Mann-Whitney U Test	.275[c]	Retain the null hypothesis.
4	The distribution of SUB RAW is the same across categories of GENDER.	Independent-Samples Mann-Whitney U Test	.080[c]	Retain the null hypothesis.
5	The distribution of SUB W C RAW is the same across categories of GENDER.	Independent-Samples Mann-Whitney U Test	.208[c]	Retain the null hypothesis.
6	The distribution of MAXIMUM DIG SPAN is the same across categories of GENDER.	Independent-Samples Mann-Whitney U Test	.332[c]	Retain the null hypothesis.
7	The distribution of P GNG is the same across categories of GENDER.	Independent-Samples Mann-Whitney U Test	.944[c]	Retain the null hypothesis.
8	The distribution of R GNG is the same across categories of GENDER.	Independent-Samples Mann-Whitney U Test	.654[c]	Retain the null hypothesis.
9	The distribution of P COMMISSION ERRORS is the same across categories of GENDER.	Independent-Samples Mann-Whitney U Test	.555[c]	Retain the null hypothesis.
10	The distribution of R COMMISSION ERRORS is the same across categories of GENDER.	Independent-Samples Mann-Whitney U Test	.436[c]	Retain the null hypothesis.

a. The significance level is .050.

b. Asymptotic significance is displayed.

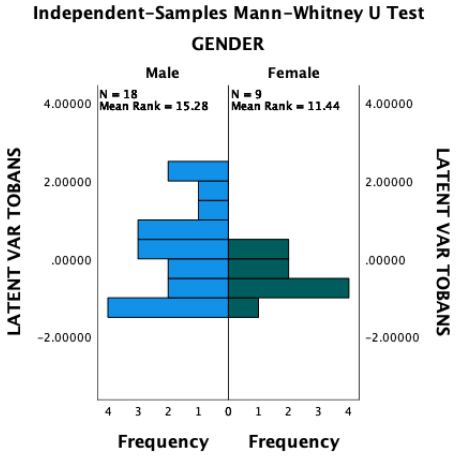
c. Exact significance is displayed for this test.

Note. LATENT VAR TOBANS= Latent Variable of TOBANS Arithmetic Subtests; ADD RAW= Addition subtest raw scores; ADD W C RAW= Addition with carry subtest raw scores; SUB RAW= Subtraction subtest raw scores; SUB W C RAW= Subtraction with carry subtest raw scores; MAXIMUM DIG SPAN= Maximum digit span; P GNG= P target Go/No Go Task; R GNG= R target Go/No Go task; P_COM_ERR= Number of Commission errors made on P target Go/No Go Task; R_COM_ERR= Number of commission errors made on R target Go/No Go Task;

LATENT VAR TOBANS across GENDER

Independent-Samples Mann-Whitney U Test Summary

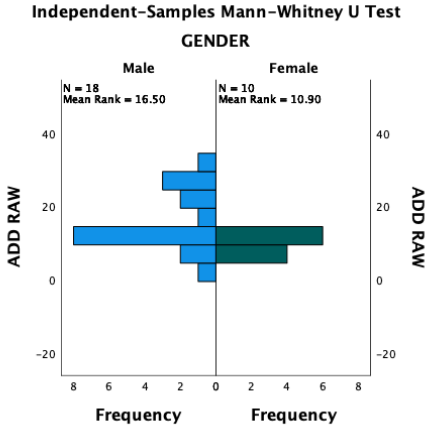
Total N	27
Mann-Whitney U	58.000
Wilcoxon W	103.000
Test Statistic	58.000
Standard Error	19.442
Standardized Test Statistic	-1.183
Asymptotic Sig.(2-sided test)	.237
Exact Sig.(2-sided test)	.253



ADD RAW across GENDER

Independent-Samples Mann-Whitney U Test Summary

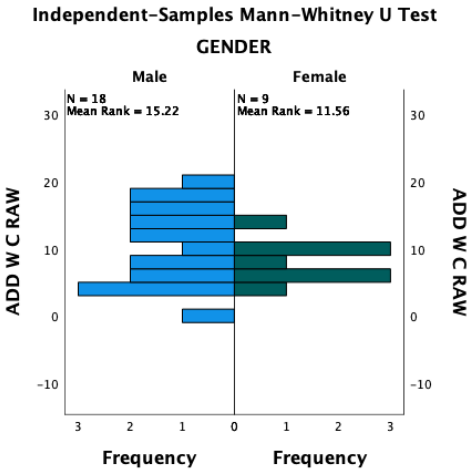
Total N	28
Mann-Whitney U	54.000
Wilcoxon W	109.000
Test Statistic	54.000
Standard Error	20.759
Standardized Test Statistic	-1.734
Asymptotic Sig.(2-sided test)	.083
Exact Sig.(2-sided test)	.089



ADD W C RAW across GENDER

Independent-Samples Mann-Whitney U Test Summary

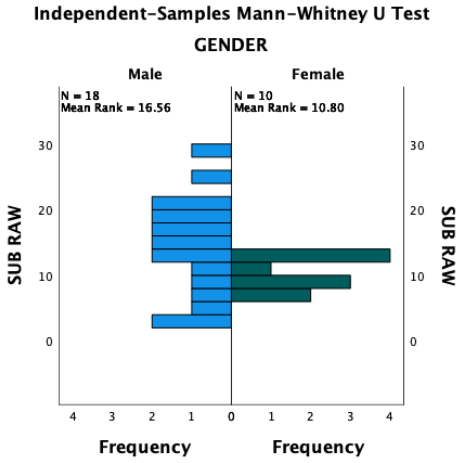
Total N	27
Mann-Whitney U	59.000
Wilcoxon W	104.000
Test Statistic	59.000
Standard Error	19.365
Standardized Test Statistic	-1.136
Asymptotic Sig.(2-sided test)	.256
Exact Sig.(2-sided test)	.275



SUB RAW across GENDER

Independent-Samples Mann-Whitney U Test Summary

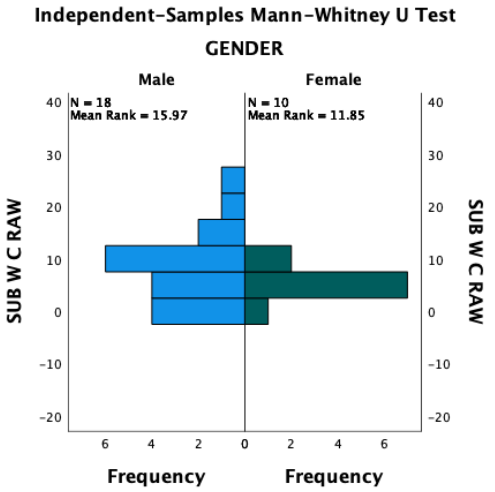
Total N	28
Mann-Whitney U	53.000
Wilcoxon W	108.000
Test Statistic	53.000
Standard Error	20.811
Standardized Test Statistic	-1.778
Asymptotic Sig.(2-sided test)	.075
Exact Sig.(2-sided test)	.080



SUB W C RAW across GENDER

Independent-Samples Mann-Whitney U Test Summary

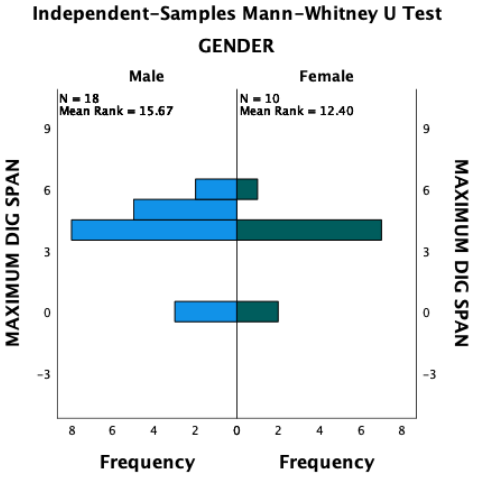
Total N	28
Mann-Whitney U	63.500
Wilcoxon W	118.500
Test Statistic	63.500
Standard Error	20.799
Standardized Test Statistic	-1.274
Asymptotic Sig.(2-sided test)	.203
Exact Sig.(2-sided test)	.208



MAXIMUM DIG SPAN across GENDER

Independent-Samples Mann-Whitney U Test Summary

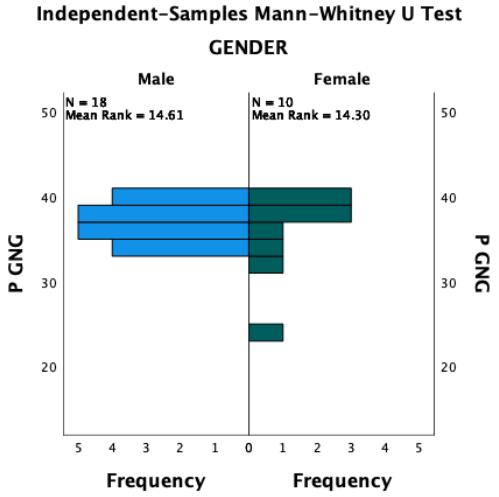
Total N	28
Mann-Whitney U	69.000
Wilcoxon W	124.000
Test Statistic	69.000
Standard Error	19.055
Standardized Test Statistic	-1.102
Asymptotic Sig.(2-sided test)	.270
Exact Sig.(2-sided test)	.332



P GNG across GENDER

Independent-Samples Mann-Whitney U Test Summary

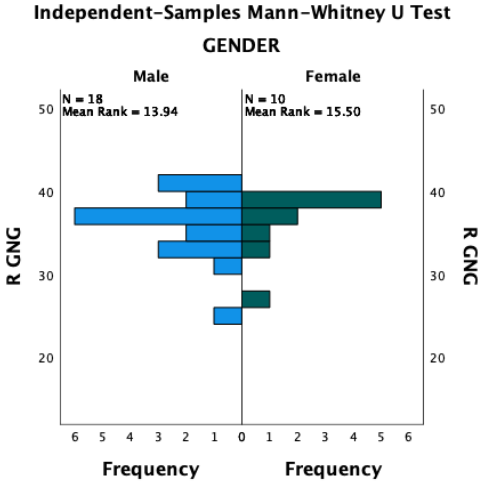
Total N	28
Mann-Whitney U	88.000
Wilcoxon W	143.000
Test Statistic	88.000
Standard Error	20.711
Standardized Test Statistic	-.097
Asymptotic Sig.(2-sided test)	.923
Exact Sig.(2-sided test)	.944



R GNG across GENDER

Independent-Samples Mann-Whitney U Test Summary

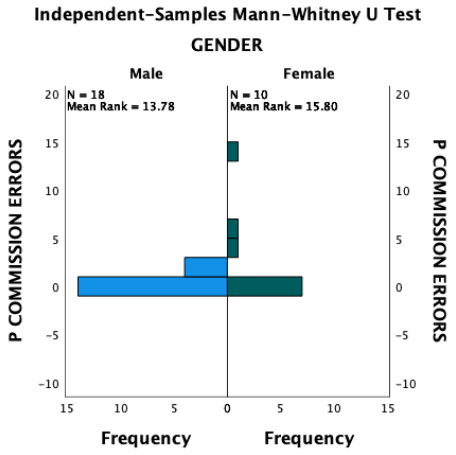
Total N	28
Mann-Whitney U	100.000
Wilcoxon W	155.000
Test Statistic	100.000
Standard Error	20.572
Standardized Test Statistic	.486
Asymptotic Sig.(2-sided test)	.627
Exact Sig.(2-sided test)	.654



P COMMISSION ERRORS across GENDER

Independent-Samples Mann-Whitney U Test Summary

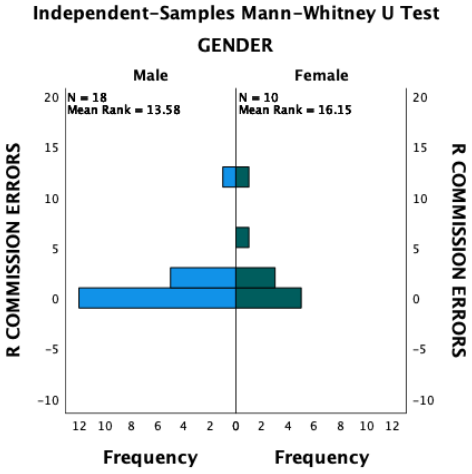
Total N	28
Mann-Whitney U	103.000
Wilcoxon W	158.000
Test Statistic	103.000
Standard Error	15.849
Standardized Test Statistic	.820
Asymptotic Sig.(2-sided test)	.412
Exact Sig.(2-sided test)	.555



R COMMISSION ERRORS across GENDER

Independent-Samples Mann-Whitney U Test Summary

Total N	28
Mann-Whitney U	106.500
Wilcoxon W	161.500
Test Statistic	106.500
Standard Error	18.195
Standardized Test Statistic	.907
Asymptotic Sig.(2-sided test)	.364
Exact Sig.(2-sided test)	.436



Appendix O: Hierarchical Regression SPSS Output

Regression

Variables Entered/Removed[a]

Model	Variables Entered	Variables Removed	Method
1	DIG SPAN[b]	.	Enter
2	TOT MOS[b]	.	Enter
3	P GNG, R OMISSION ERRORS, R COMMISSION ERRORS, P OMISSION ERRORS, P COMMISSION ERRORS, R GNG[b]	.	Enter
4	GENDER[b]	.	Enter

a. Dependent Variable: LATENT VAR TOBANS

b. All requested variables entered.

Note. LATENT VAR TOBANS= Latent Variable of TOBANS Arithmetic Subtests; DIGSPAN= Digit Span task total score; TOTMOS= Participant age in months; P GNG= P target Go/No Go Task; R GNG= R target Go/No Go task; P_OM_ERR= Number of omission errors made on P target Go/No Go Task; P_COM_ERR= Number of Commission errors made on P target Go/No Go Task; R_OM_ERR= Number of omission errors made on R target Go/No Go Task; R_COM_ERR= Number of commission errors made on R target Go/No Go Task

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.451[a]	.203	.171	.91041696	.203	6.368	1	25	.018
2	.536[b]	.287	.228	.87881674	.084	2.830	1	24	.105
3	.614[c]	.377	.100	.94853445	.090	.434	6	18	.847
4	.630[d]	.396	.077	.96076438	.019	.545	1	17	.471

a. Predictors: (Constant), DIG SPAN

b. Predictors: (Constant), DIG SPAN, TOT MOS

c. Predictors: (Constant), DIG SPAN, TOT MOS, P GNG, R OMISSION ERRORS, R COMMISSION ERRORS, P OMISSION ERRORS, P COMMISSION ERRORS, R GNG

d. Predictors: (Constant), DIG SPAN, TOT MOS, P GNG, R OMISSION ERRORS, R COMMISSION ERRORS, P OMISSION ERRORS, P COMMISSION ERRORS, R GNG, GENDER

Note. LATENT VAR TOBANS= Latent Variable of TOBANS Arithmetic Subtests; DIGSPAN= Digit Span task total score; TOTMOS= Participant age in months; P GNG= P target Go/No Go Task; R GNG= R target Go/No Go task; P_OM_ERR= Number of omission errors made on P target Go/No Go Task; P_COM_ERR= Number of Commission errors made on P target Go/No Go Task; R_OM_ERR= Number of omission errors made on R target Go/No Go Task; R_COM_ERR= Number of commission errors made on R target Go/No Go Task

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5.279	1	5.279	6.368	.018[b]
	Residual	20.721	25	.829		
	Total	26.000	26			
2	Regression	7.464	2	3.732	4.832	.017[c]
	Residual	18.536	24	.772		
	Total	26.000	26			
3	Regression	9.805	8	1.226	1.362	.277[d]
	Residual	16.195	18	.900		
	Total	26.000	26			
4	Regression	10.308	9	1.145	1.241	.335[e]
	Residual	15.692	17	.923		
	Total	26.000	26			

a. Dependent Variable: LATENT VAR TOBANS

b. Predictors: (Constant), DIG SPAN

c. Predictors: (Constant), DIG SPAN, TOT MOS

d. Predictors: (Constant), DIG SPAN, TOT MOS, P GNG, R OMISSION ERRORS, R COMMISSION ERRORS, P OMISSION ERRORS, P COMMISSION ERRORS, R GNG

e. Predictors: (Constant), DIG SPAN, TOT MOS, P GNG, R OMISSION ERRORS, R COMMISSION ERRORS, P OMISSION ERRORS, P COMMISSION ERRORS, R GNG, GENDER

Note. LATENT VAR TOBANS= Latent Variable of TOBANS Arithmetic Subtests; DIGSPAN= Digit Span task total score; TOTMOS= Participant age in months; P GNG= P target Go/No Go Task; R GNG= R target Go/No Go task; P_OM_ERR= Number of omission errors made on P target Go/No Go Task; P_COM_ERR= Number of Commission errors made on P target Go/No Go Task; R_OM_ERR= Number of omission errors made on R target Go/No Go Task; R_COM_ERR= Number of commission errors made on R target Go/No Go Task

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients			95.0% Confidence Interval for B	
		B	Std. Error	Beta	t	Sig.	Lower Bound	Upper Bound
1	(Constant)	-.625	.303		-2.060	.050	-1.250	.000
	DIG SPAN	.563	.223	.451	2.524	.018	.103	1.022
2	(Constant)	-4.784	2.489		-1.922	.067	-9.921	.354
	DIG SPAN	.452	.225	.362	2.006	.056	-.013	.916
	TOT MOS	.046	.027	.303	1.682	.105	-.010	.102
3	(Constant)	8.479	61.156		.139	.891	-120.006	136.963
	DIG SPAN	.450	.252	.360	1.783	.091	-.080	.980
	TOT MOS	.040	.033	.264	1.189	.250	-.030	.110
	P GNG	.261	1.006	.899	.259	.798	-1.852	2.374
	R GNG	-.572	1.130	-2.193	-.506	.619	-2.947	1.803
	P OMISSION ERRORS	.189	1.022	.373	.185	.855	-1.958	2.337
	P COMMISSION ERRORS	.263	.999	.712	.264	.795	-1.835	2.362
	R OMISSION ERRORS	-.566	1.172	-1.252	-.483	.635	-3.028	1.897
	R COMMISSION ERRORS	-.647	1.129	-1.960	-.574	.573	-3.019	1.724
4	(Constant)	20.241	63.962		.316	.756	-114.707	155.189
	DIG SPAN	.441	.256	.353	1.723	.103	-.099	.981
	TOT MOS	.035	.034	.233	1.020	.322	-.037	.108
	P GNG	-.029	1.092	-.100	-.027	.979	-2.333	2.275
	R GNG	-.561	1.145	-2.151	-.490	.631	-2.977	1.855
	P OMISSION ERRORS	-.117	1.115	-.232	-.105	.917	-2.471	2.236
	P COMMISSION ERRORS	.007	1.070	.019	.007	.995	-2.250	2.264
	R OMISSION ERRORS	-.558	1.187	-1.236	-.470	.644	-3.063	1.946
	R COMMISSION ERRORS	-.647	1.143	-1.959	-.566	.579	-3.060	1.765
	GENDER	-.362	.491	-.174	-.738	.471	-1.399	.674

a. Dependent Variable: LATENT VAR TOBANS

Note. LATENT VAR TOBANS= Latent Variable of TOBANS Arithmetic Subtests; DIGSPAN= Digit Span task total score; TOTMOS= Participant age in months; P GNG= P target Go/No Go Task; R GNG= R target Go/No Go task; P_OM_ERR= Number of omission errors made on P target Go/No Go Task; P_COM_ERR= Number of Commission errors made on P target Go/No Go Task; R_OM_ERR= Number of omission errors made on R target Go/No Go Task; R_COM_ERR= Number of commission errors made on R target Go/No Go Task

Excluded Variables[a]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	TOT MOS	.303[b]	1.682	.105	.325	.914
	P GNG	.198[b]	1.111	.278	.221	.999
	R GNG	.207[b]	1.157	.259	.230	.980
	P OMISSION ERRORS	-.078[b]	-.430	.671	-.087	.988
	P COMMISSION ERRORS	-.196[b]	-1.093	.285	-.218	.985
	R OMISSION ERRORS	.027[b]	.142	.888	.029	.948
	R COMMISSION ERRORS	-.289[b]	-1.678	.106	-.324	1.000
	GENDER	-.213[b]	-1.180	.250	-.234	.960
2	P GNG	.224[c]	1.315	.202	.264	.991
	R GNG	.190[c]	1.093	.286	.222	.976
	P OMISSION ERRORS	-.171[c]	-.945	.354	-.193	.915
	P COMMISSION ERRORS	-.169[c]	-.969	.343	-.198	.975
	R OMISSION ERRORS	-.017[c]	-.090	.929	-.019	.928
	R COMMISSION ERRORS	-.241[c]	-1.397	.176	-.280	.960
	GENDER	-.158[c]	-.872	.392	-.179	.917
3	GENDER	-.174[d]	-.738	.471	-.176	.638

a. Dependent Variable: LATENT VAR TOBANS

b. Predictors in the Model: (Constant), DIG SPAN

c. Predictors in the Model: (Constant), DIG SPAN, TOT MOS

d. Predictors in the Model: (Constant), DIG SPAN, TOT MOS, P GNG, R OMISSION ERRORS, R COMMISSION ERRORS, P OMISSION ERRORS, P COMMISSION ERRORS, R GNG

Note. LATENT VAR TOBANS= Latent Variable of TOBANS Arithmetic Subtests; DIGSPAN= Digit Span task total score; TOTMOS= Participant age in months; P GNG= P target Go/No Go Task; R GNG= R target Go/No Go task; P_OM_ERR= Number of omission errors made on P target Go/No Go Task; P_COM_ERR= Number of Commission errors made on P target Go/No Go Task; R_OM_ERR= Number of omission errors made on R target Go/No Go Task; R_COM_ERR= Number of commission errors made on R target Go/No Go Task